# MASS TIMBER BUILDING ENCLOSURE BEST PRACTICE DESIGN GUIDE

## A guide for designers, construction professionals, and building developers

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RDH BUILDING SCIENCE

# ABOUT THIS GUIDE

The intent of this guide is to educate designers, construction professionals, and building developers on best practice enclosure design principles for mass timber enclosures, including roofs, walls, and floor/soffit conditions.

Version 2 of this guide includes expanded discussion on fire protection, examples of higher-performing enclosure systems, and design discussion for balcony assemblies. Additionally, new photos and illustrations are provided throughout the guide.

This guide is a compilation of new and previously published content authored by RDH Building Science; resources used to compile this document are included in the references and additional resources sections of this guide.

This guide is a companion to *Moisture Risk Management Strategies for Mass Timber Buildings*, also published by RDH Building Science.

# ABOUT THE AUTHOR

For over 25 years, RDH Building Science has been committed to leading innovation and change in the design and construction of buildings. We believe that all buildings can be made better through the integration of science, design, and construction expertise. Our team has contributed to mass timber projects throughout the US and Canada and has built a strong understanding of considerations needed to create a durable and high-performance enclosure.

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*Catalyst Building, Spokane, Washington (Michael Green Architecture). Photo credit: Benjamin Benschneider*

# 1 – INTRODUCTION

Interest is growing in mass timber products to diversify the use of wood as a building material within mid-rise and high-rise construction. Architects and developers are attracted to mass timber for many reasons, including the construction speed of mass timber projects, the opportunity for carbon sequestration, and the aesthetic appeal of mass timber construction. Many mass timber buildings have been built in the US and Canada over the past decade; these early examples of modern mass timber construction, along with testing and research, prompted new building codes that have allowed mass timber buildings up to 12 and even 18 stories in only a few years' time.

The design and performance of mass timber assemblies within a building differ from traditional light-frame, structural steel, or mass concrete assemblies that have long dominated the low-rise residential construction market in the US and Canada. Modern mass timber buildings are constructed of engineered wood products made from multiple layers of sawn lumber. These layers are either mechanically fastened or glued together to form a solid panel, beam, or column. Mass timber has unique physical properties that influence its moisture sensitivity; mass timber has a relatively high capacity to store moisture and a relatively slow potential for drying.

Although the use of mass timber within building construction is not a new concept, many mass timber enclosure products are still relatively new to markets in the US and Canada. The newness of these products—combined with the stipulations of modern/new building codes, the demand for expeditious construction in any climate or season, and the uniqueness of mass timber's moisture properties—requires the designer to apply careful attention and additional foresight to mass timber projects. This added effort will ensure that the long-term durability of the mass timber is not compromised.

Common mass timber products are defined and summarized in Table 1. Products commonly used for building enclosure applications are comprised of dimension lumber such as cross-laminated timber (CLT), nail-laminated timber (NLT), and dowel-laminated timber (DLT) in addition to veneer, strand, and sheet products. This wide range of products provides many options for design applications as well as the range of design challenges, performance characteristics, and construction advantages discussed in this guide.

*Table 1* Mass Timber Product Summary

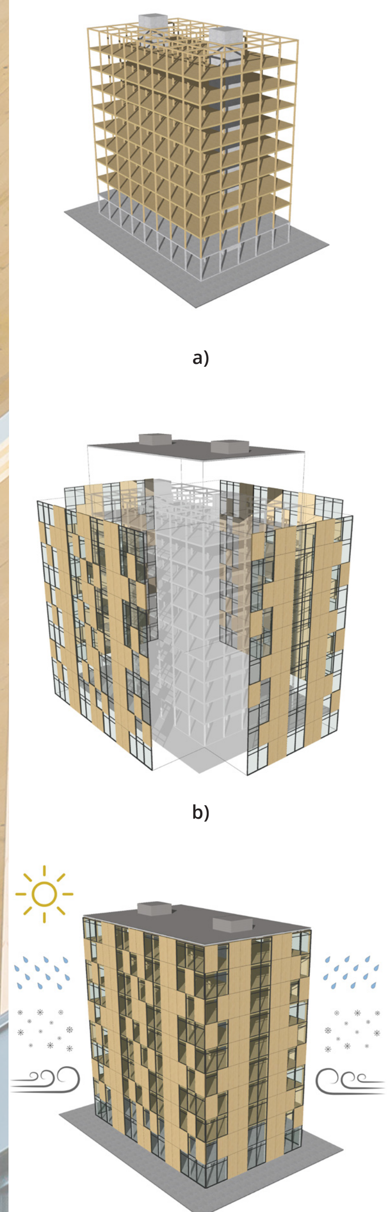
| Dimension Lumber Properties | | | | |
|---|---|---|---|---|
| **Component** | **Description** | **Common Sizes*** | **Typical Applications** | **Considerations** |
| <br>**NLT**<br>Nail-Laminated Timber | A solid wood structural element made of 2x dimension lumber stacked on edge and fastened together with nails. Plywood or OSB sheathing may be added to one face for increased shear strength [1]. | *Lumber Dimensions*<br>Thickness: nominal 2x, 3x, or 4x<br>Width: nominal 4 to 12 inches<br>*Panel Size*<br>Width: 4 feet or 8 feet<br>Length: up to 60 feet | • Floors and roofs in one-way spans<br>• Less commonly used in wall applications | • Ease of fabrication; special equipment or facilities not required<br>• Not readily machinable because of metal fasteners within panels<br>• Typically has one "show" side exposed to the interior due to the need for sheathing on the other side |
| <br>**DLT**<br>Dowel-Laminated Timber | A solid wood structural element consisting of dimension lumber on edge and fastened together with friction-fit hardwood dowels. Plywood or OSB sheathing may be added to one face for increased shear strength [1]. | *Lumber Dimensions*<br>Thickness: nominal 2x, 3x, or 4x<br>Width: nominal 4 to 12 inches<br>*Panel Size*<br>Width: up to 12 feet<br>Length: up to 60 feet | • Floors and roofs in one-way spans<br>• Less commonly used in wall applications | • Readily machinable due to the lack of metal fasteners<br>• Finger-jointed board splices increase strength<br>• Typically has one "show" side exposed to the interior due to the need for sheathing on the other side |
| <br>**CLT**<br>Cross-Laminated Timber | A solid wood structural element made of several layers of lumber boards (typically 3 to 7 or more) glued together in alternating directions. Typically, boards are glued on their wide face but may also be glued on their edge [2]. | *Lumber Dimensions*<br>Thickness: 5/8 to 2 inches<br>Width: 2.4 to 9.5 inches; also uses custom milled lumber dimensions<br>*Panel Size*<br>Width: 2, 4, 8, and 10 feet<br>Lengths: up to 60 feet<br>Thickness: 20 inches or less | • Floors and roofs in two-way spans and in wall applications | • Excellent panel length and width dimensional stability due to cross lamination<br>• Readily machinable due to the lack of metal fasteners within panels<br>• May be exposed on either side of the panel if protected from the elements<br>• Two-way stiffness and strength without the use of additional sheathing layers |
| <br>**GLT**<br>Glue-Laminated (Glulam) Timber | A solid wood element made of individual wood laminations glued together. Laminations are selected and positioned based on their performance characteristics and run parallel with the length of the member [1]. | *Lumber Dimensions*<br>Thickness: 1 3/8 inches for southern pine and 1 1/2 inches for Western species<br>*Product Size*<br>Net width: 2 1/2 to 10 3/4 inches; stock beam widths range from 3 1/8 to 6 3/4 inches<br>Depth: 9 to 36 inches<br>Length: 8 to 52 feet [3] | • Columns, beams, and headers<br>• Although less common, glulam has also been used in panel applications for floors/roofs and walls by laying up deeper sections | • High structural capacities allow for use in long spans<br>• Load-carrying capacity may be significantly affected by field notching, cutting, and drilling<br>• Dimensional movement primarily in the depth<br>• Most glulam is fabricated with tight moisture control and wood selection and coated in the factory to reduce moisture sensitivity |
| *Common sizes are listed. Refer to manufacturer-specific information for all available sizes. | | | | |



***Table 1 (continued)*** *Mass Timber Product Summary*

| Veneer, Strand, and Sheet Properties | | | | |
|---|---|---|---|---|
| **Component** | **Description** | **Common Sizes*** | **Typical Applications** | **Considerations** |
| <br>**LSL**<br>Laminated Strand Lumber | A wood strand element made of flaked fibers that are glued together. The strands are selected to meet specific strength requirements. This product has the appearance of OSB. | *Typical Dimensions*<br>Width: 1 1/2 to 3 1/2 inches<br>Depth: 1 1/2 to 16 inches<br>Length: 3 to 28 feet | • Columns, beams, and headers<br>• Could also be used in panel applications for floors/roofs and walls | • High strength, stiffness, dimensional stability, and good fastener retention |
| <br>**LVL**<br>Laminated Veneer Timber | A wood element made of wood veneer sheets adhered together. The veneers are selected to meet specific strength requirements. | *Typical Dimensions*<br>Thickness: 3/4 to 7 inches<br>Depth: 9 1/2 to 23 7/8 inches<br>Length: 48 to 80 feet | • Columns, beams, and headers<br>• Could also be used in panel applications for floors/roofs and walls, though for enhanced dimensional stability, the cross-lamination of MPP (below) is more suitable for panels | • Economical; the most widely used structural composite lumber product<br>• Not typically used as an exposed structural element<br>• High strength, high stiffness, and dimensional stability except when one side of the panel is differentially wetted from the other, where curling can be expected in a parallel veneer application |
| <br>**MPP**<br>Mass Plywood Panel | A wood element made of wood veneer sheets adhered together and with wood fibers primarily oriented with the long axis of the member, though engineered with cross orientation to improve dimensional stability over parallel LVL. | *Typical Dimensions*<br>Thickness: 1-inch increments up to 24 inches<br>Floor, roof, and wall panels: can be manufactured as large as 11 feet by 48 feet, and up to 12 inches thick<br>Beams and columns: up to 24 inches thick | • Floors and roofs in two-way spans and in wall applications | • Readily machinable |
| <br>**PSL**<br>Parallel Strand Lumber | A wood element made of veneer strands oriented with the long axis of the member. The veneers are selected to meet specific strength requirements. | *Typical Dimensions*<br>Thickness: 2 11/16, 3 1/2, 5 1/4, and 7 inches<br>Depth: 9 1/4 to a maximum of 18 inches<br>Square or rectangular column dimensions: 3 1/2, 5 1/4, 7, and 9 1/4 inches<br>Length: up to 66 feet | • Columns, beams, and headers | • High strength, high stiffness, and dimensional stability<br>• Typically used as an exposed structural element<br>• Treated PSL can be specified in high-humidity exposures |
| *Common sizes are listed. Refer to manufacturer-specific information for all available sizes. | | | | |

*The enclosure of a mass timber building being craned into place. UIBC Brock Commons Tall Wood House, University of British Columbia, Vancouver (Acton Ostry Architects). Photo credit: naturallywood.com*



a)

b)

c)

***Figure 1*** *A mass timber building model showing a) the mass timber structure, b) the enclosure, and c) the building subjected to various environmental loads.*

# 2 – THE BUILDING ENCLOSURE

The building enclosure (also sometimes called the "envelope") physically separates conditioned (e.g., indoor) space from unconditioned (e.g., outdoor) spaces (see Figure 1). This separation is achieved by a system of materials, components, and assemblies that control the flow of heat, air, and moisture, and provide other functions such as fire and acoustic separation.

Over its service life, the building enclosure is subjected to environmental loads of liquid water and water vapor, air, and heat in addition to other loads such as fire, smoke, light, sound, and insects. The enclosure must also counteract lateral wind loads and seismic loads, and it must provide support of its own weight and other vertical loads (if it is load-bearing). These loads are transferred back to the building's primary structure. Thoughtful design of the building enclosure requires consideration of all environmental and structural loads imposed on the enclosure over its expected service life.

The outdoor environment varies with climate and local site conditions while the environment indoors differs with building use and occupant behavior. Thus, the designer must consider climate, microclimate, site conditions, and building use and operation when evaluating the loads acting on the enclosure. Liquid water, predominately rainwater but also snow melt and runoff, is typically the most critical load. Other loads—air, heat, and water vapor (i.e., vapor)—are caused by differences between the indoor and outdoor conditions.

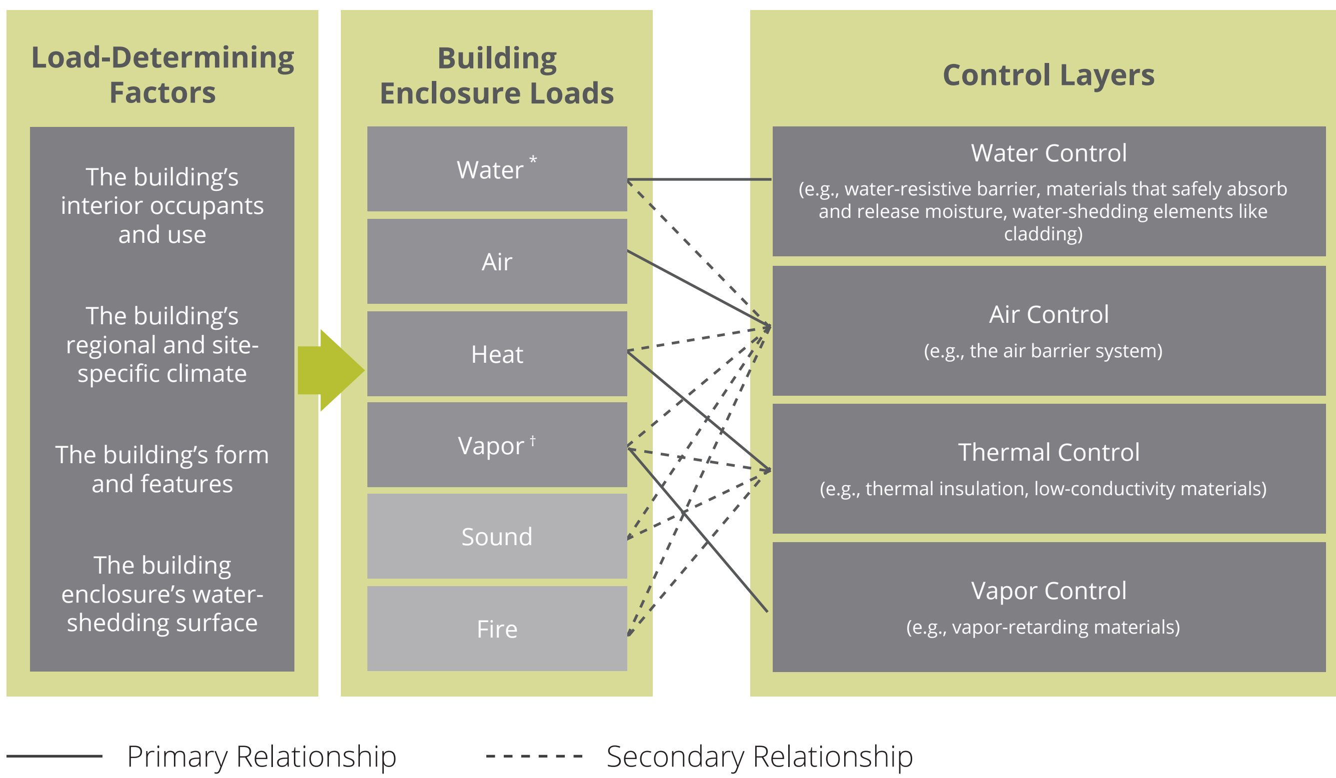
*Thoughtful design of the building enclosure requires consideration of all environmental and structural loads imposed on the enclosure over its expected service life.*

# CONTROL LAYERS

Control layers are stand-alone materials or systems of materials in the building enclosure that manage the indoor and outdoor loads of a building. Control layers are designed to manage a specific load or loads. Figure 2 describes the building enclosure loads and the associated control layers with examples of each.

An industry best practice is to use the concept of control layers to evaluate assemblies and details so the designer, contractor, and owner teams understand the role and importance of each enclosure material or system. This approach ensures the project team can identify and evaluate layers that are missing, discontinuous (if required to be continuous), or inappropriately redundant. Use of this approach can also limit the number of gaps in the construction documents and reduce excessive materials and related costs.

The remainder of this chapter describes how the control layer concept is applied specifically to mass timber enclosure design for long-term performance.




* Water is defined here as precipitation (rain, snow, hail, etc.) and groundwater as well as water resulting from condensation.
† Vapor is defined here as the water vapor in air.

***Figure 2*** *Control layer relationships for mass timber enclosures. When a control layer is intentionally designed to control a specific load, that layer has a primary relationship with the building enclosure load. Some control layers also control other loads indirectly (i.e., secondary relationships).*



# WATER CONTROL

For moisture-sensitive products like wood, the most critical enclosure load is often liquid water. Liquid water can occur in many forms, including rain, snow, and ice melt. When wood absorbs water, the wood can shrink and swell, causing dimensional changes to the mass timber panels. These changes can create gaps or collisions between panels, at panel penetrations, and in surrounding elements such as columns or wall structures. Rapid dimensional changes can also cause checking. Exposing wood to moisture (in both liquid and vapor forms) can increase the risk for corrosion of metal fasteners or connections, microbial growth, and decay (see Figure 3). Mass timber sections can retain large amounts of water for extended periods of time if sufficient drying is not available, further increasing these risks and possibly the loss of structural integrity.

The major factors that affect liquid water absorption are the type of wood species, the grain orientation, and the time of exposure. For example, wood absorbs moisture much more rapidly through its end grain (i.e., longitudinal direction) than through the transverse directions [4]. In the US and Canada, the annual rainfall levels vary from low levels in desert and arid climates to more extreme levels in coastal regions. Rain exposure is also increased by wind speeds, resulting in wind-driven rain (i.e., driving rain). Wind speeds generally increase with height; thus, taller mass timber buildings are likely to see greater water loads than shorter wood-framed structures.

The timing of rainfall events can be as important as the amount of rainfall. For example, a rainfall followed by colder temperatures and/or high humidity levels provides little opportunity for drying. For mass timber panels that have been erected but are not yet properly protected from construction-phase moisture, even small amounts of wetting followed by minimal drying can be risky. Wet snow accumulation and snowmelt can create wetting in horizontal panels similar to rain events.

***Figure 3*** *Decomposition of a CLT floor panel caused by an impermeable membrane trapping moisture in the wood and preventing drying.*

*The major factors that affect liquid water absorption are the wood species, the grain orientation, and the time of exposure.*

## Water Management at Roofs and Floors

During building occupancy, water at the building's roof is managed by the roof membrane, the perimeter flashings, and the roof drainage system. To promote long-term performance of the roof assembly, this guide recommends that a durable, fully adhered (e.g., multi-ply) roof membrane be installed on the roof, especially where temporary roof membranes over the mass timber structure are not used. Best practice guidance for general roof design and installation of materials can be found in roofing manuals developed by the National Roofing Contractors Association.

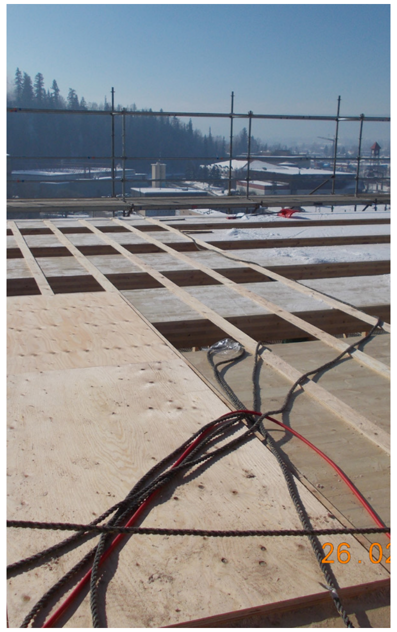
Assemblies that use mass timber panels covered by a membrane with a low vapor permeance require special attention. These membranes can trap moisture within the mass timber element, limiting drying to the interior of the building. In this case, the mass timber element could take years to dry depending on how wet the element was prior to cover. While wetting should be avoided wherever possible, additional steps may be necessary under these conditions to protect the wood from damage during the drying period. These assemblies may benefit by including a space above the mass timber components (if possible) to improve their drying potential. An example of a project where top-side venting was achieved is shown in Figure 4.

Mass timber floor assemblies may not see exterior water exposure such as rain and snow during occupancy, but they can be exposed to moisture in bathrooms, showers, laundry rooms, and food-preparation areas. These areas should be treated with a waterproofing system and drainage for incidental water to reduce the moisture exposure of the mass timber floor panel.

Floor assemblies will also likely experience some exposure to rainfall or snowfall during construction, as shown in Figure 5. For additional design guidance and recommendations for minimizing moisture-related risks during construction and occupancy, refer to *Moisture Risk Management Strategies for Mass Timber Buildings*, also published by RDH Building Science.

*To promote long-term performance of the roof assembly, this guide recommends that a durable, fully adhered (e.g., multi-ply) roof membrane be installed on the roof, especially where temporary roof membranes over the mass timber structure are not used.*





a)

b)

***Figure 4*** *A flat batten venting approach. Structural sheathing is shown a) over the top of the battens, and b) on the underside (interior view) of the vented assembly. The project was designed in this manner to improve the drying ability of the mass timber roof assembly during construction and in-service.*

***Figure 5*** *CLT floor assembly exposed to moisture during construction.*

## Water Management at Walls

Water at wall assemblies is managed first by the water-shedding surface, which includes cladding, flashings, and other surfaces facing the exterior environment. Water is managed secondly by the water-resistive barrier (WRB) system. The best practice strategy for water control in mass timber walls is use of a drained and ventilated cladding (i.e., rainscreen cladding). This is a common construction practice in the wetter regions of the US and Canada. While this strategy may seem excessive in some climates, it provides necessary redundancy in the water management design for mass timber walls. This design approach also provides an outlet for inward-driven moisture from more absorptive claddings (i.e., reservoir claddings)—such as stucco, brick, and stone masonry—and other porous cladding materials. This approach is illustrated in Figure 6.

In a rainscreen cladding design, the water-shedding surface, including the cladding, sheds most of the water load from the exterior surface of the wall. Moisture that penetrates the water-shedding surface will run down the backside of the cladding, the strapping, the exterior insulation (where present), or the WRB system before it reaches the flashings at floor levels and around wall penetrations, such as windows. The WRB is a secondary plane of protection against liquid water and the innermost plane that can safely manage and drain any incidental moisture load.

In many cases, this same WRB membrane is also sealed and detailed as the air barrier system of the building enclosure. The air barrier system reduces the exchange of air between the building's indoor and outdoor environments. This membrane is described in the next section.

*The best practice strategy for water control in mass timber walls is use of a drained and ventilated cladding (i.e., rainscreen cladding).*

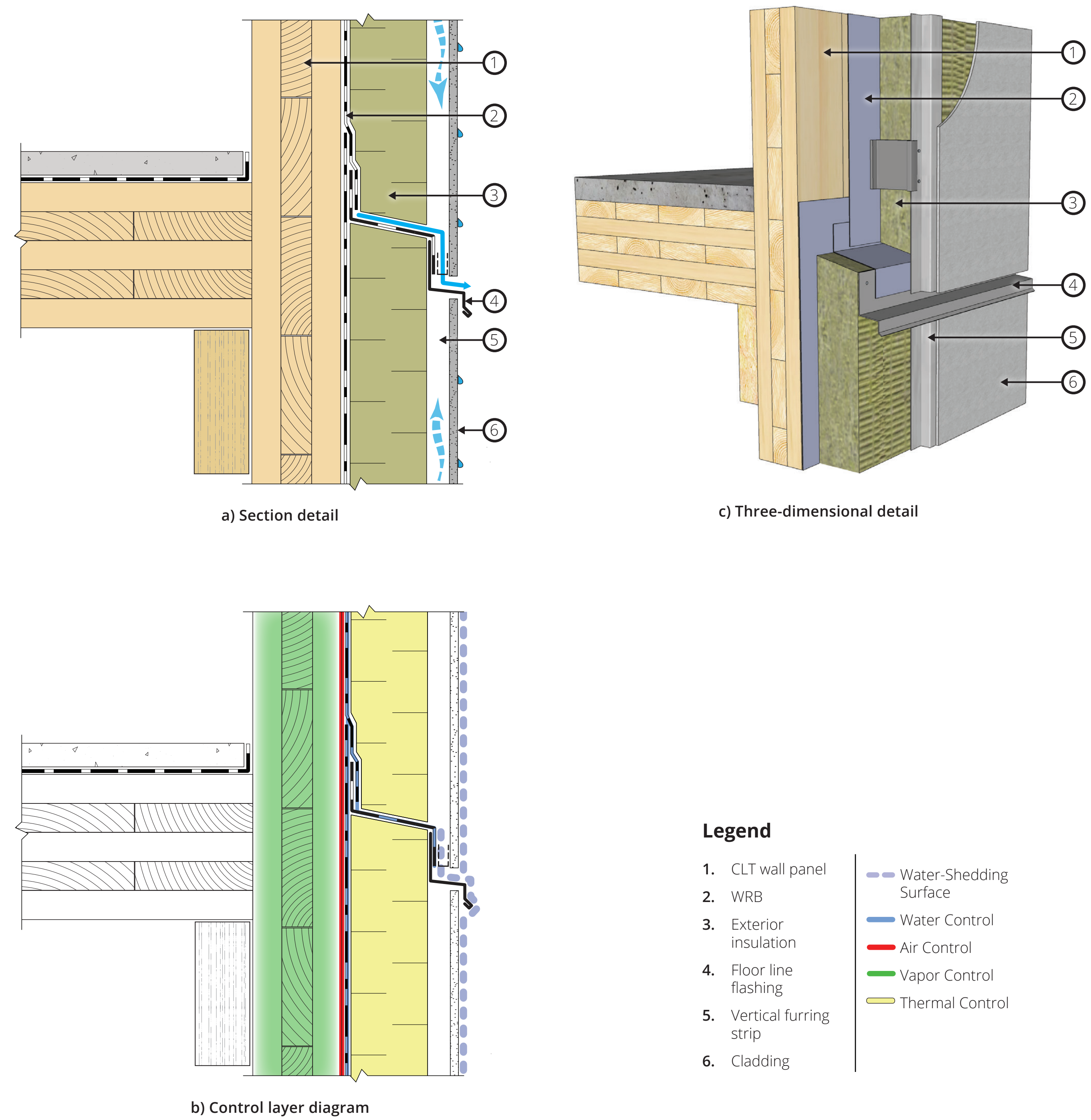



***Figure 6*** *Typical rainscreen cladding design at a CLT wall floor line. Details show a) a section detail of the enclosure layers, b) the location of the control layers, and c) a three-dimensional cutaway section of the interface.*

# AIR CONTROL

Controlling airflow across the building enclosure reduces energy consumption, increases thermal comfort, and minimizes the movement of water vapor through the assembly. Controlling airflow also minimizes the transfer of sound, smoke, fire, and airborne contaminants between environments. In the US and Canada, managing air flow across the building enclosure is a requirement of US and Canadian building codes and is accomplished by using an air barrier system, i.e., a three-dimensional system of materials designed, constructed, and acting to control airflow across and within the building enclosure. An air barrier system has five basic requirements: continuity, strength, durability, stiffness, and air impermeability. These requirements are discussed in the remainder of this section [5].

## Continuity

The air barrier system must be continuous. To meet this requirement in a mass timber enclosure, the air barrier system must be continuous at all joints, penetrations, and interfaces with other assemblies. This means the enclosure must rely on many different materials acting together to be airtight. Examples of details with air barrier continuity are shown in Chapter 4.

## Strength

The air barrier system must be strong enough to transfer air pressures back to the supporting structure. A mass timber structure is strong enough to carry this load, but the membrane and components of the air barrier system should be fully adhered or mechanically attached to the wood panel. However, in high wind exposure applications, a mechanically attached system may be insufficient to transfer air pressures back to the structure without being damaged. Figure 7 shows an example of a fully adhered air barrier system that also serves as the WRB membrane.

*Figure 7* *A fully adhered air barrier and WRB membrane over a mass timber wall substrate.*

## Durability

The air barrier system must be durable enough to perform over the expected service life of the building enclosure. In a mass timber assembly, this requires that the air barrier system withstand the temperature fluctuations, building and wood substrate movement, air pressure differentials, and environmental exposures (e.g., UV and contaminants) that may occur during the building's life cycle.

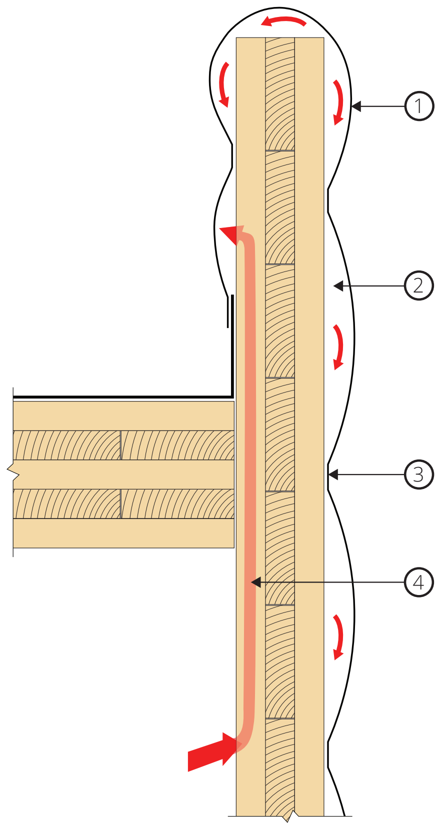
The strength and durability properties discussed above are specific to the building service life; however, air barrier system materials must also demonstrate strength and durability during the construction phase to ensure long-term performance. Considerations must be made for UV exposure, moisture exposure, wind pressures/gusts, and trade activities. Placement of the air barrier system at a protected location, such as on the exterior of the mass timber wall panel behind the exterior insulation, helps to address some of these concerns.

Mass timber substrates present a unique challenge for some air barrier systems; potential gaps or checks in the wood surface and between plies make it more difficult to use a liquid-applied air barrier membrane than a sheet product. Careful attention is needed to avoid splits in the membrane while the membrane cures and during the building's service life. Sheet-based products typically fare better in this regard.

## Stiffness

The air barrier system must be resistant to any air pressure-induced loads from wind, stack effect, and/or mechanical system operations without significantly distorting, delaminating, or becoming damaged. These loads are due mainly to the air pressure differential acting across the air barrier. In a mass timber assembly, this pressure differential is best overcome by applying a fully adhered air barrier membrane directly on the wood panels, because the membrane's adhesion to the stiff wood substrate can resist both positive and negative pressures.

In low-rise applications with lower wind exposure, a mechanically attached membrane can be sandwiched between the exterior insulation and the wood panel, though more care must be taken to address airflow behind the membrane at membrane details and interfaces. Figure 8 demonstrates this challenge at a roof parapet, where a mechanically attached membrane can be difficult to make airtight.




**Legend**

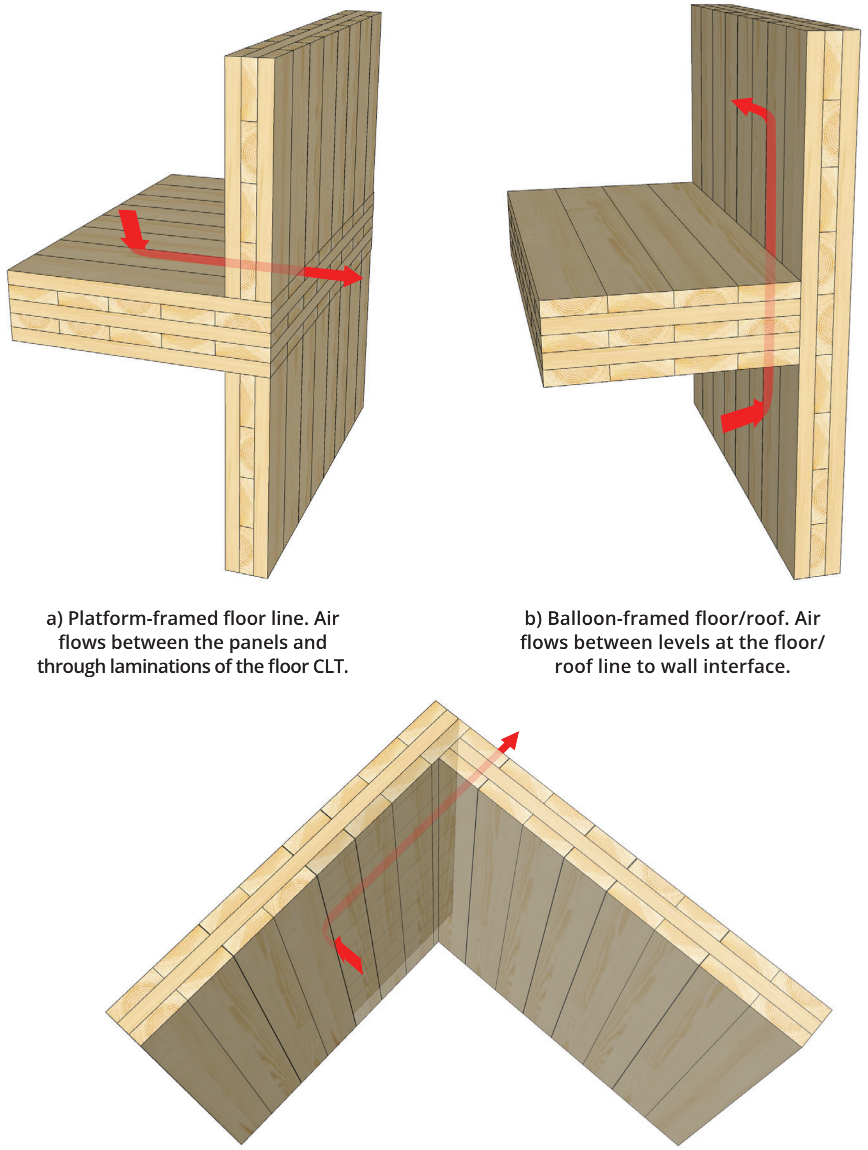
1. Mechanically attached air barrier membrane
2. Airflow causing billowing and potential membrane damage
3. Intermittent fasteners per manufacturer requirements
4. Airflow pathway through mass timber joints and plies

*Figure 8* *Example parapet detail where the air barrier membrane is billowing due to air movement across the roof-to-parapet interface.*

> *An air barrier system has five basic requirements: continuity, strength, durability, stiffness, and air impermeability.*

## Air Impermeability

The air barrier system must resist airflow. While wood panels may initially have a very low air permeability when tested in a laboratory setting, the actual interfaces between weathered panels in the field and the small spaces or gaps between each lamination of the panel allow for the passage of air when the panels are structurally connected. Thus, mass timber panels are not part of the air barrier system. A best practice in mass timber enclosure design is to extend air barrier membranes continuously around all mass timber components, including around soffits, up and over parapets, and across floor lines. Examples of air flow paths through CLT panels are shown in Figure 9. Similar air flow paths through other types of mass timber components can occur.



a) Platform-framed floor line. Air flows between the panels and through laminations of the floor CLT.

b) Balloon-framed floor/roof. Air flows between levels at the floor/roof line to wall interface.

c) CLT panel corner. Air flows through wall laminations and the panel corner connection.

***Figure 9*** *Airflow paths through CLT panel gaps and interfaces.*

# THERMAL CONTROL

Heat flows across the building enclosure when there is a temperature difference between the indoor and outdoor environments—the greater the temperature difference, the greater the potential transfer of heat (i.e., thermal load). The thermal load tends to be greater in colder climates where the outdoor temperature dips below indoor temperatures throughout much of the year. Insulation is an essential component for energy efficient buildings in most, if not all, US and Canada climate zones.

Most building codes across North America typically reference some version of the International Energy Conservation Code (IECC) [6], ASHRAE 90.1 [7], or the National Energy Code of Canada for Buildings (NECB) [8] to set the minimum required level of insulation. Minimum insulation requirements generally fall within the R-15 to R-28 (RSI 2.6 to RSI 4.9) range for walls, R-20 to R-49 (RSI 3.5 to RSI 8.6) for roofs, and R-0 to R-30 (RSI 0 to RSI 5.3) for floors. Project-specific performance requirements may require greater levels of insulation than that required by code depending on energy use targets and energy model assumptions. Selection and placement of the insulation can also improve thermal comfort for the occupants, provide a buffer from outdoor noise, and help manage condensation risk within the enclosure.

While dedicated insulation layers are the primary means of thermal control, mass timber panels also contribute to the assembly's thermal performance because wood has a relatively low thermal conductivity compared to other common structural materials like concrete and steel.

*Insulation is an essential component for energy efficient building in most, if not all US and Canada climate zones.*


*Figure 10* In-progress installation of exterior mineral wool insulation.

The thermal resistance of wood per inch varies based on moisture content and species, and type of product; but for most commonly used North American softwood species, a thermal resistance of R-1.2 per inch can be used for dimension lumber products. Table 2, Table 3, and Table 4 summarize typical panel thicknesses and associated R-values for reference. In most scenarios, the thermal resistance of the wood panel alone is not great enough to meet the required thermal performance of the assembly, so additional insulation, like that shown in Figure 10, will be needed. This guide recommends locating insulation outboard of the wood panel to keep the wood panel closer to the indoor temperature, which minimizes condensation risk and limits temperature and relative humidity fluctuations. Examples of typical mass timber assemblies and their effective R-value calculations are shown in Figure 11.

When considering heat flow through the mass timber enclosure, the mass of the timber panel can also impact the thermal performance of the assembly by moderating heat flow through thermal storage. Depending on climate and other building factors, this thermal storage and throttling effect may reduce both annual and peak heating and cooling requirements, particularly in warmer climates with large daily temperature variations. Building codes that reference the IECC or ASHRAE 90.1 may credit this thermal mass effect with less-stringent prescriptive insulation requirements for mass wall and floor assemblies if the mass timber assembly exceeds the minimum heat capacity required by the IECC or ASHRAE 90.1. Use of this approach will largely depend on the thickness of the panel, the wood species, and code interpretations by the local governing jurisdiction.

*This guide recommends locating insulation outboard of the wood panel to keep the wood panel closer to the indoor temperature, which minimizes condensation risk and limits temperature and relative humidity fluctuations.*

***Table 2*** *CLT Panel Thermal Resistance Values. Table is based on CLT panels with a typical lamination thickness of 1 3/8 inches. Lamination sizes vary by manufacturer [9], [10].*

| Number of Laminations | Thickness (inches) | Panel Thermal Resistance (R-value) | |
|---|---|---|---|
| | | R-1.0/inch | R-1.2/inch |
| 3 | 4 1/8 | 4.1 | 5.0 |
| 4 | 5 1/2 | 5.5 | 6.6 |
| 5 | 6 7/8 | 6.9 | 8.3 |
| 6 | 8 1/4 | 8.3 | 9.9 |
| 7 | 9 5/8 | 9.6 | 12 |
| 8 | 11 | 11 | 13 |

***Table 3*** *MPP Thermal Resistance Values [10]*

| Thickness (inches) | Panel Thermal Resistance (R-value) |
|---|---|
| | R-1.4/inch |
| 2 | 2.8 |
| 3 | 4.2 |
| 4 | 5.6 |
| 5 | 7.0 |
| 6 | 8.4 |
| 7 | 9.8 |
| 8 | 11 |
| 9 | 13 |
| 10 | 14 |
| 11 | 15 |
| 12 | 17 |

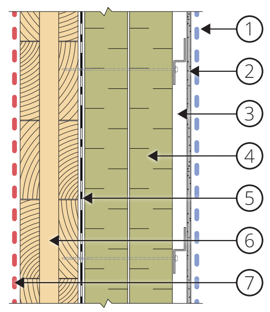
***Table 4*** *NLT and DLT Panel Thermal Resistance Values [10]*

| Lamination Nominal Size | Lamination Depth (inches) | Species* (R-value per inch) | Panel Thermal Resistance (R-value) | | | | |
|---|---|---|---|---|---|---|---|
| | | | No Sheathing | OSB Sheathed | Plywood Sheathed | | |
| | | | | 7/16-inch (R-0.62) | 1/2-inch (R-0.79) | 5/8-inch (R-0.85) | 3/4-inch (R-1.1) |
| 2x4 | 3 1/2 | SPF, HF (R-1.2) | 4.2 | 4.8 | 5.0 | 5.1 | 5.3 |
| 2x4 | 3 1/2 | DFL (R-1.0) | 3.5 | 4.1 | 4.3 | 4.4 | 4.6 |
| 2x6 | 5 1/2 | SPF, HF (R-1.2) | 6.6 | 7.2 | 7.4 | 7.5 | 7.7 |
| 2x6 | 5 1/2 | DFL (R-1.0) | 5.5 | 6.1 | 6.3 | 6.4 | 6.6 |
| 2x8 | 7 1/4 | SPF, HF (R-1.2) | 8.7 | 9.3 | 9.5 | 9.6 | 9.8 |
| 2x8 | 7 1/4 | DFL (R-1.0) | 7.3 | 7.9 | 8.0 | 8.1 | 8.3 |
| 2x10 | 9 1/4 | SPF, HF (R-1.2) | 11 | 12 | 12 | 12 | 12 |
| 2x10 | 9 1/4 | DFL (R-1.0) | 9.3 | 9.9 | 10 | 10 | 10 |

* SPF = Spruce-Pine-Fir; HF = Hem-Fir; DFL = Douglas-Fir-Larch

***Figure 11*** *Typical mass timber assemblies. See Figure 12 for each assembly's effective R-value calculation.*

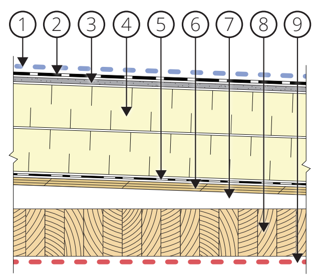
a) Exterior Wall (plan view)




**Legend**

1. Exterior air film
2. Cladding
3. Ventilated and drained air cavity
4. Exterior insulation
5. Air barrier and water-resistive barrier
6. Mass timber panel
7. Interior air film

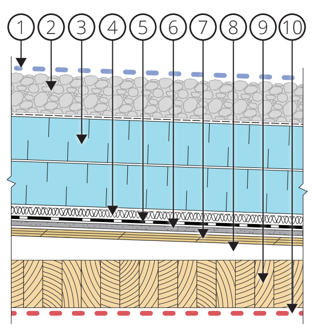
b) Conventional Roof




**Legend**

1. Exterior air film
2. Roof membrane
3. Coverboard
4. Insulation
5. Air and vapor barrier
6. Structural sheathing
7. Air space
8. Mass timber panel
9. Interior air film

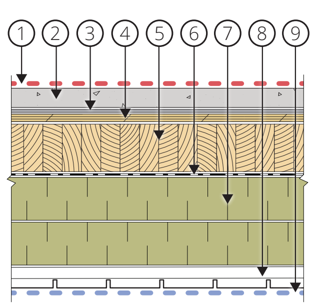
c) Protected-Membrane Roof




**Legend**

1. Exterior air film
2. Ballast
3. Insulation
4. Drainage composite
5. Waterproofing membrane
6. Coverboard
7. Structural sheathing
8. Air space
9. Mass timber panel
10. Interior air film

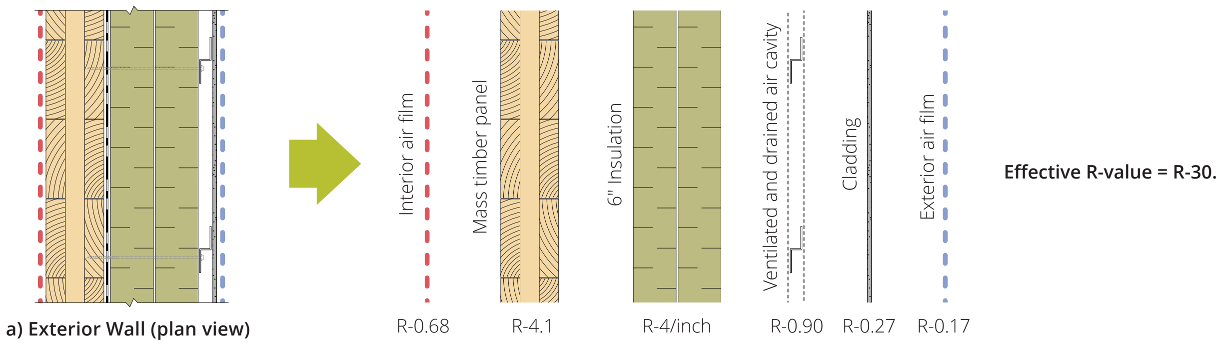
d) Exposed Floor



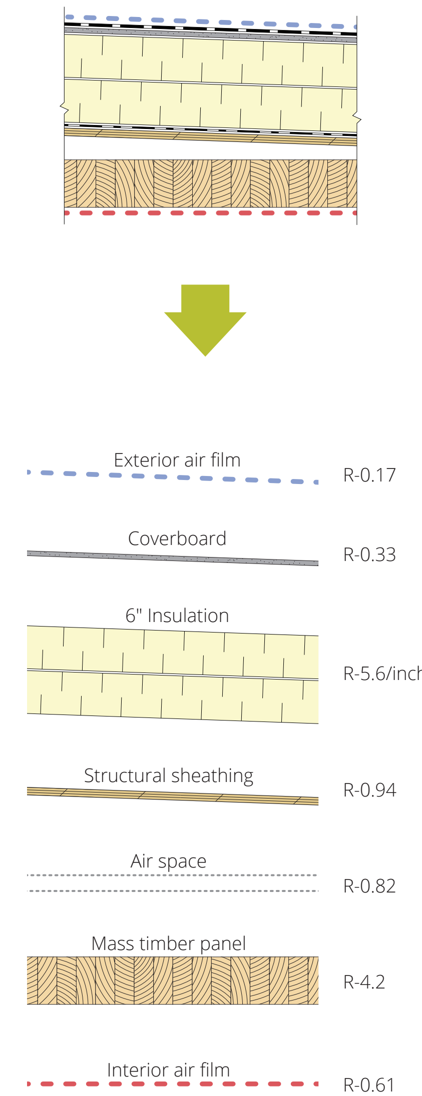

**Legend**

1. Interior air film
2. Cementitious topping
3. Acoustic mat
4. Structural sheathing
5. Mass timber panel
6. Air barrier
7. Exterior insulation
8. Soffit air space and panel
9. Exterior air film



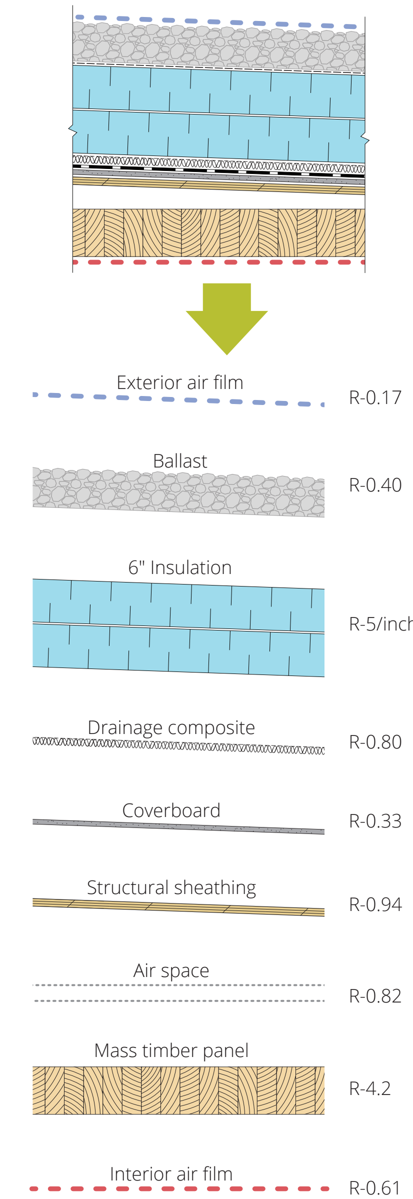



b) Conventional Roof



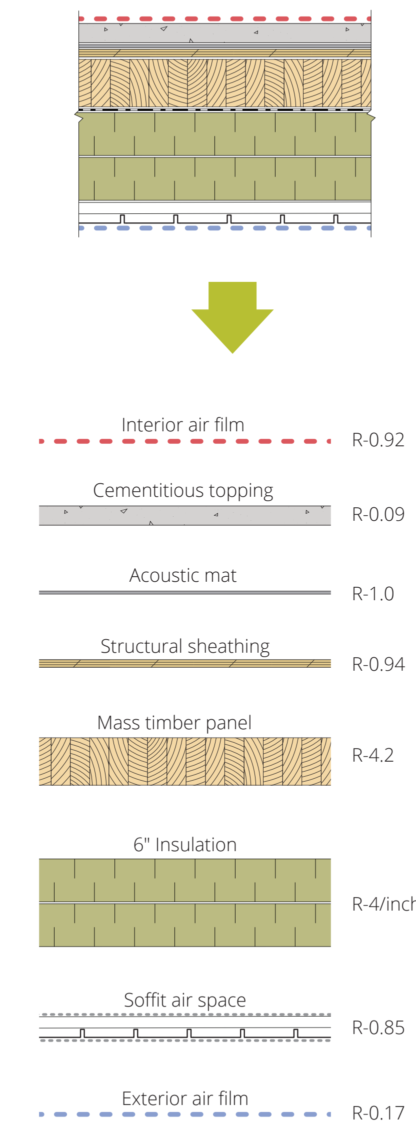

**Effective R-value = R-40.7**

c) Protected-Membrane Roof




**Effective R-value = R-38.3**

d) Exposed Floor




**Effective R-value = R-32.2**

***Figure 12*** *Effective R-value calculations for the mass timber enclosure assemblies shown in Figure 11. Assembly layers not included within each calculation are considered negligible for the purposes of this R-value calculation [7].*

## Thermal Bridging Through Exterior Insulation

When a more highly conductive element, such as metal, bridges an insulation layer, it creates a path of lower resistance to heat flow. This path is commonly called a thermal bridge and will degrade the thermal performance of the insulation layer and overall assembly thermal performance. For mass timber assemblies, it is common to locate the insulation exterior of the timber, keeping the large structural connections inboard of the insulation layer; thus, thermal bridges at field-of-wall and roof assemblies tend to result from a need to transfer wind loads and cladding loads back to the structure. Beyond the field-of-wall and roof assemblies, common thermal bridges that need to be addressed include windows, parapets, balconies, and canopies.

Cladding and roof fasteners can have a significant impact on the overall thermal performance of the enclosure and can vary widely based on the system used. Generally, more thermally efficient options for these attachment points rely on materials with lower thermal conductivity, such as stainless steel, fiberglass, and/or intermittent attachments through the insulation (e.g., clips or fasteners) in lieu of continuous metal furring. Figure 13 shows one example of a cladding attachment system and Figure 14 describes four common examples of cladding attachment systems for exterior-insulated mass timber wall applications.

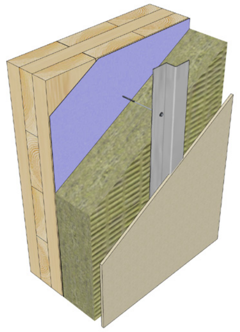
For further discussion on the comparative performance and advantages of various attachment systems, refer to *Cladding Attachment Solutions for Exterior-Insulated Commercial Walls* authored by RDH Building Science [11].

***Figure 13*** *A clip and rail cladding attachment system and mineral wool insulation make up the thermal control layer of the mass timber wall assembly on this building.*



## LONG SCREWS WITH FURRING STRIPS

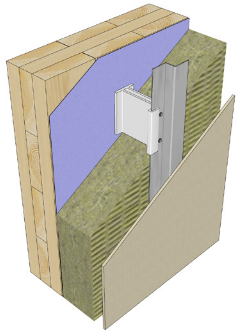
Long screws through exterior insulation are a cost-effective and thermally efficient option for the attachment of light- to medium-weight claddings. With this system, the cladding is attached to treated vertical wood or steel furring strips placed against the face of the exterior insulation. The furring strips are fastened back through the insulation to the mass timber panel.



a)

## CLIP AND RAIL SYSTEM

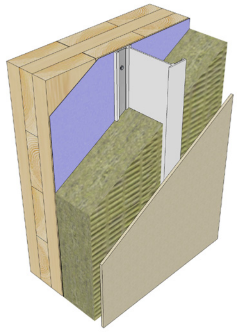
With clip and rail systems, the cladding is attached to vertical or horizontal metal girts. The girts, or rails, are attached to intermittent clips that bridge the insulation and are attached to the mass timber structure. The insulation may be rigid or semi-rigid mineral fiber; however, semi-rigid insulation is typically easier to fit around the clips.



b)

## VERTICAL GIRTS

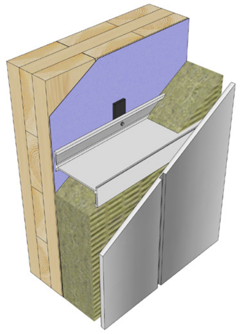
Vertically oriented girts are a common form of cladding attachment with rigid or semi-rigid insulation types. Continuous metal girts significantly degrade the performance of exterior insulation, but more thermally efficient girts made of less thermally conductive materials are available.



c)

## HORIZONTAL GIRTS

Continuous horizontal girts can significantly degrade the performance of exterior insulation unless non-metal girts are used. Horizontal girts are shimmed to provide a continuous drainage plane at the face of the WRB and to seal around girt fastener penetrations through the membrane. Rigid or semi-rigid insulation types can be used with this attachment approach.



d)

***Figure 14*** *Four cladding attachment options: a) long screws with furring strips, b) clip and rail system, c) vertical girts, and d) horizontal girts.*

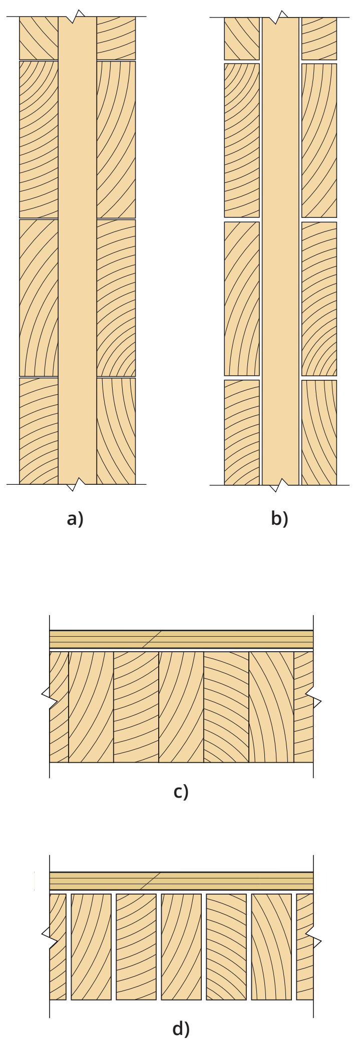



*Figure 15* Example of cross-sectional changes of a CLT wall panel when a) laminations expand due to swelling, and b) laminations return to a lower moisture content. Example of the cross-sectional changes of an NLT floor or roof panel when c) laminations expand due to swelling, and d) laminations return to a lower moisture content.

# WATER VAPOR CONTROL

Wood panels exchange moisture with the surrounding air. The amount of moisture gain or loss largely depends on the relative humidity but also on temperature and other factors. When the wood no longer gains or loses moisture, it has reached equilibrium with the environment.

Wood shrinks when it loses moisture and swells when it gains moisture. Dimensional changes are the greatest in the direction of the annual growth rings (i.e., tangential)—about half as much across the growth rings (i.e., radial) and usually very small along the grain (i.e., longitudinal) [12]. Wood used in construction and mass timber manufacturing always has a mixture of growth ring orientations.

With care in the manufacturing, transport, storage, and construction of mass timber products, the moisture content of the wood will only change within a small range, and consequently the shrinkage or swelling will be much smaller. The dimensional change that a cross section of softwood wood may undergo due to moisture loss or gain can be estimated by using an average shrinkage coefficient of 0.20% to 0.25% per 1% change in moisture content.

Examples of growth ring orientation and dimensional changes are shown in Figure 15.

Although the potential shrinkage of individual boards would be similar in the width and thickness directions, this is not always the case. In CLT, the cross-lamination of boards minimizes the in-plane dimensional changes due to the good longitudinal stability of the adjacent lamina, just like typical plywood. Because NLT and DLT are mechanically attached and lack cross-laminations, they do not have this same stability; this means gaps will open up between these panels at splices and between laminations. In any case, the shrinking and swelling of individual boards can cause warping and checking in CLT, NLT, and DLT wood panel surfaces if large cyclic moisture content changes occur. In MPPs, shrinkage and swelling will cause distortion of the entire panel. In MPPs with cross-grain laminations versus LVL (which typically have parallel laminations), panel bowing is controlled, making MPP more dimensionally stable for panels than LVL.

Figure 16 illustrates the relationship between equilibrium moisture content and relative humidity for an environment at 70°F (21°C). The ANSI/APA (2012) standard for CLT manufacturing requires that the moisture content of lumber at the time of manufacture be 12% ± 3%; however, most mass timber is manufactured in the 12% to 14% range [13]. The typical equilibrium moisture content of wood materials within building enclosures ranges from 7% to 12% (approximately 30% to 60% relative humidity) depending on the interior relative humidity conditions. This means that wood panels exhibit only small changes in moisture content after installation when adjusting to typical building service conditions, depending on the indoor and outdoor conditions. However, if the panels become wet during construction or the in-service conditions are not typical—such as lower or higher than normal indoor humidity conditions or large fluctuations in humidity—it may be necessary to regulate the indoor relative humidity over a long period of time to stabilize the moisture content and avoid dimensional changes, checking, and warping in the wood panels.

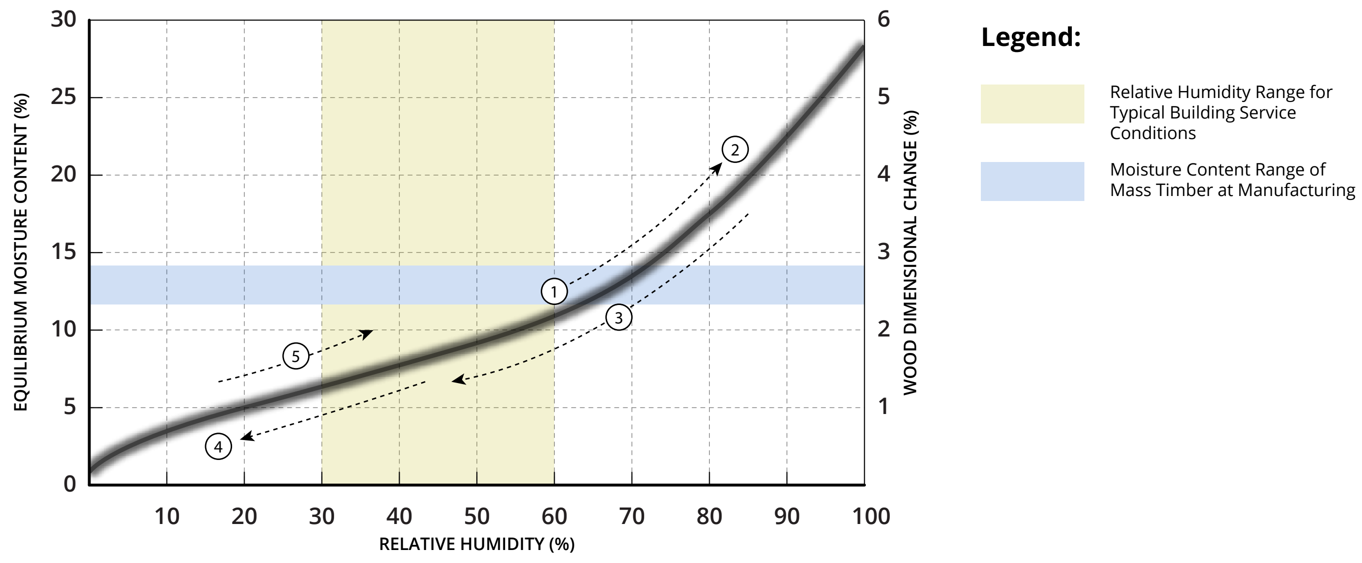



*Figure 16* Generic sorption isotherm for wood at 70°F (21°C) (adapted from [14]). The moisture content, and resulting dimensional change, of mass timber throughout the construction and service life can be described as: (1) Mass timber at manufacturing and delivery to site; (2) Wetting and expansion of the mass timber during construction; (3) Drying and shrinkage of mass timber to reach typical building service conditions; (4) Further potential for mass timber drying and shrinkage in lower than normal relative humidity service conditions; (5) Stabilization of the interior relative humidity minimizes moisture content changes and resulting dimensional changes of the mass timber.

*With care in the manufacturing, transport, storage, and construction of mass timber products, the moisture content of the wood will only change within a small range, and consequently the shrinkage (or swelling) will be much smaller.*

## Vapor Permeability and Vapor Barriers

Water vapor transport across a mass timber assembly can be managed by relying on the mass timber's ability to function as a vapor retarder and by controlling air leakage across the enclosure. Airflow transports significantly larger amounts of water vapor than vapor diffusion alone; however, both transport mechanisms must be controlled properly in relation to the building's interior and exterior climatic conditions.

The vapor permeance of North American softwood lumber species used for CLT at normal indoor relative humidity levels of 30% to 50% generally ranges from less than 0.17 perms (10 ng/Pa·s·m$^2$) to as much as 2.0 US perms (125 ng/ Pa·s·m$^2$) based on dry cup values for a 1-inch (25-mm) thick piece of lumber [15], [16]. When considering mass timber panels manufactured of softwood species and at typical panel thicknesses, the approximate vapor permeance is relatively low, as shown in Table 5 and Table 6; a typical 3-ply CLT panel, 2x4 NLT or DLT panel with sheathing, and 4-inch MPP meets the requirement for a vapor barrier (e.g., Class II vapor retarder) based on the US and Canada building code requirements [17]. Thicker panels are even less permeable. Therefore, where the mass timber is located on the warm side of the insulation, a supplemental vapor retarder is not necessary.

***Table 5*** *Vapor Permeance of CLT at Different Thicknesses and Relative Humidity Levels [16]*

| Relative Humidity | Vapor Permeance, US Perms | | |
|---|---|---|---|
| | 4 inches | 6 inches | 8 inches |
| 20% | 0.06 | 0.04 | 0.03 |
| 50% | 0.31 | 0.21 | 0.15 |
| 80% | 1.0 | 0.68 | 0.51 |

***Table 6*** *Vapor Permeance of MPP at Different Thicknesses and Relative Humidity Levels [10]. This table includes 1/2-inch plywood for reference.*

| Relative Humidity | Vapor Permeance, US Perms | | | |
|---|---|---|---|---|
| | 1/2 inch | 4 inches | 6 inches | 8 inches |
| 10% | 0.21 | 0.027 | 0.018 | 0.013 |
| 30% | 0.57 | 0.071 | 0.047 | 0.035 |
| 50% | 1.5 | 0.19 | 0.13 | 0.10 |
| 70% | 4.0 | 0.50 | 0.33 | 0.25 |
| 90% | 11 | 1.4 | 0.91 | 0.69 |

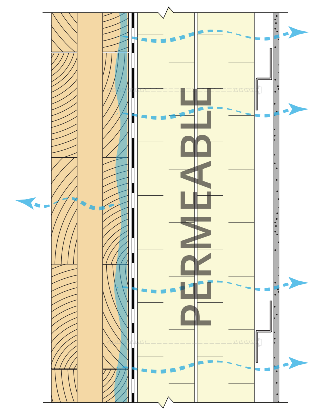
## Maintaining Drying Potential

Mass timber in an enclosure assembly is inherently a vapor retarder, and for all practical purposes, it inhibits the flow of water vapor across the assembly. As a result, adding a vapor barrier or other low-permeability materials is not desirable; it reduces the drying potential of the mass timber panel, as illustrated in Figure 17. Although this strategy is straightforward for wall designs, this concept is complicated in roof assemblies where vapor-impermeable water control layers are often needed.

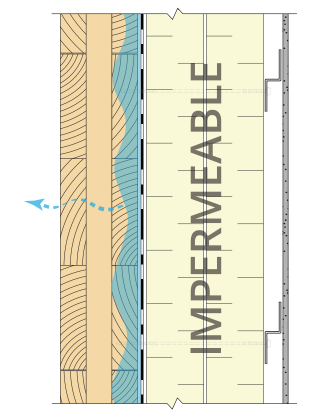
The use of impermeable materials within a wall or roof assembly can minimize drying if the panel becomes wet during construction. This is particularly relevant when roof membranes are applied over mass timber roofs and when concrete toppings or membranes are applied over mass timber floors. Therefore, it is important that mass timber panels are sufficiently dry prior to the installation of any enclosure layers or that the assembly is specifically designed to allow for drying of construction moisture.

Consider also the vapor impermeability of the wood in relation to the assembly's insulation placement and type as well as the placement and properties of other air and water control membranes. The long-term durability aim with all assemblies is to avoid water vapor accumulation within the assembly. Hygrothermal modeling [18] followed by field monitoring research at the University of Waterloo [19] [20] and by FPInnovations [21] [22] has shown the potential risk of encapsulating an initially wet CLT behind vapor-impermeable materials installed on either side of the panel. Field investigations of damaged mass timber have also confirmed this risk where water is able to reach the mass timber behind vapor-impermeable membranes and is unable to dry out.

For additional guidance on managing moisture and planning for drying, refer to *Moisture Risk Management Strategies for Mass Timber Buildings*, also published by RDH Building Science.




a)




b)

***Figure 17*** *Example wall assembly (plan view) showing the relative rate of drying toward the building exterior: a) vapor-permeable exterior insulation and a vapor-permeable air barrier and WRB membrane; b) vapor-impermeable exterior insulation or impermeable air barrier and WRB membrane. While the interior laminations of the CLT can dry out relatively quickly, the outer lamination behind the impermeable membrane and insulation will take months or years to fully dry out. Although shown on a wall assembly in this figure, the need for vapor-permeable layers to support assembly drying also applies to floor/soffit assemblies.*

*The long-term durability aim with all assemblies is to avoid water vapor accumulation within the assembly.*

# FIRE PROTECTION

While fire protection is not the primary focus of this guide, the unique fire and combustibility characteristics of mass timber assemblies should be considered to attain the appropriate level of safety required by local building and fire codes.

This section outlines the key design considerations for fire protection of enclosures that are code compliant relative to building and fire codes. The requirements defining how fire protection in mass timber enclosures is achieved varies among codes and jurisdictions in the US and Canada, and they are evolving as mass timber becomes more commonplace. In all cases, a qualified engineer should be retained to provide design input for the enclosure assembly makeup and detailing related to fire protection. This design work will generally follow one of three basic approaches as listed below, with some overlap where necessary:

1) **Acceptable Solutions (Excluding Testing)**: Both the 2021 International Building Code (IBC) in the US and the 2020 edition of the National Building Code (NBC) of Canada contain specific provisions for the design and construction of mass timber assemblies that achieve the required fire protection requirements set out in the codes. These provisions include code-specified assembly configurations, generic listed assemblies, acceptable calculation methods, and/or reference to previous accepted fire testing in determining the mass timber enclosure assemblies and detailing. Specific provisions for fire protection of mass timber includes encapsulation (i.e., noncombustible coverings, referred to as encapsulated mass timber construction or EMTC), minimum material thicknesses, and limitations on the use of other combustible materials. Using acceptable solutions that exclude full-scale testing is considered the baseline design approach for fire protection of mass timber enclosure assemblies.
2) **Full-Scale Testing**: Canadian and US building codes also reference standardized tests designed to demonstrate that a specific building enclosure assembly is an acceptable solution and meets the fire protection code requirements. These standards indicate the performance characteristics of assemblies and components that comply with the fire protection requirements without necessarily following specified construction approaches or design methodologies. Testing of mass timber building enclosure assemblies to demonstrate compliance is a significant undertaking and is typically associated with product development work rather than conducted for a specific building project. However, testing may be needed to allow some flexibility in the enclosure assembly design without having to seek alternative compliance.
3) **Alternative Compliance**: Codes also typically allow alternative solutions (known as alternative materials, design, and methods of construction and equipment in the IBC) for designs that don't follow the specific design, construction, or full-scale testing methodologies outlined as acceptable solutions. This work would be completed by a qualified engineer with specialized knowledge of the components, materials, and configurations being used. A qualified engineer must conduct a careful analysis using engineering judgement and justify the use of assemblies and details (without using testing) so that a building official can allow them as alternative solutions for a specific building project. While potentially less arduous than full-scale testing, this approach still requires substantial involvement by the fire engineer, and presents the risk of a design being rejected.

*RDH wishes to thank the following individuals for their expert review and contribution to the Fire Protection section of this guide:*

*Steven Craft & Richard Michels,*
*CHM Fire Consultants Ltd.*

*www.chmfire.ca*

*Andrew Harmsworth,*
*GHL Consultants Ltd.*

*www.ghl.ca*



In all compliance approaches, three primary fire protection/resistance parameters are considered: fire resistance rating, exterior fire spread, and firestopping. To best demonstrate the application of these code requirements, the following section describes the applicable testing associated with these parameters that would be used if full-scale testing were employed to show compliance.

## Fire Resistance Rating of the Assembly

The fire resistance rating is defined as the time in minutes or hours that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria (see illustration in Figure 18a). It is used to assign minimum ratings for key assemblies in the structure and enclosure, including roofs.

Mass timber enclosure assemblies (as with all assembly types) are required by code to meet the code-specified fire resistance rating requirements. For walls, ratings are set out based on key structural and exposure conditions, such as whether the assembly is structurally load-bearing or non-load-bearing. The fire resistance rating for load-bearing assemblies is typically greater because they have to be able to support the building structure. Non-load-bearing assemblies still must meet fire protection requirements, but they are usually lower and governed by the distance from, and therefore the fire risk associated with fire spread to, adjacent buildings and properties. For roofs, similar fire protection requirements apply.

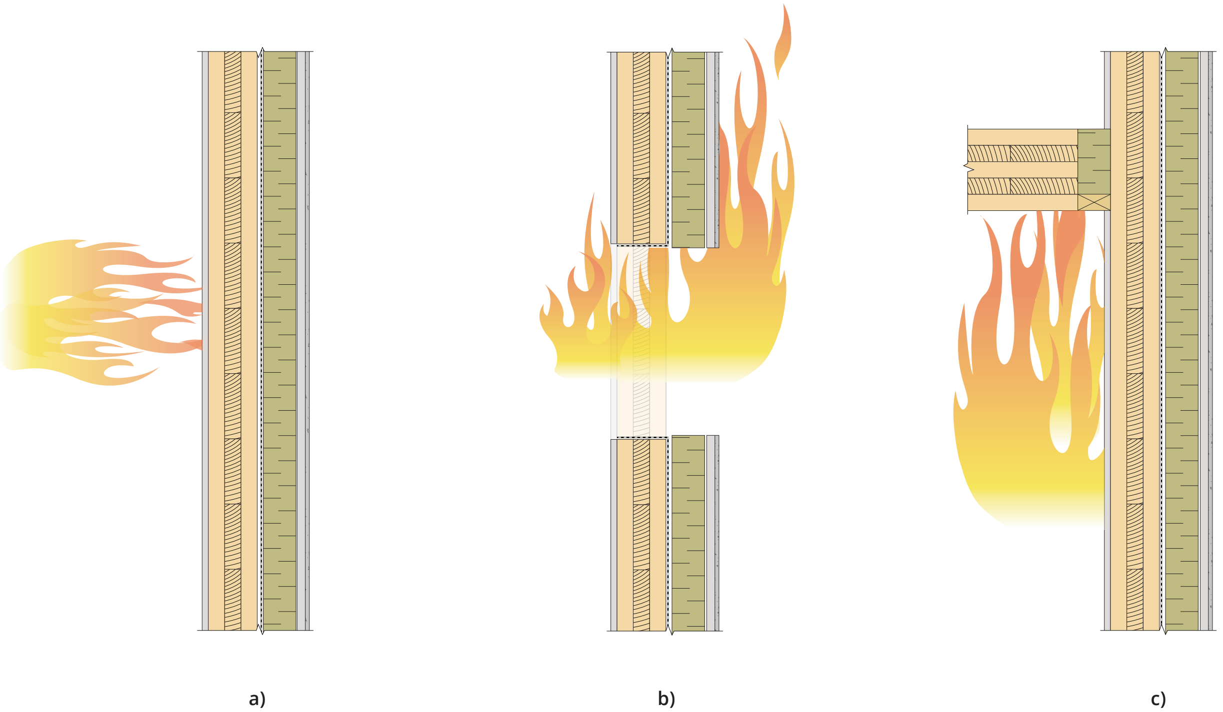



*__Figure 18__ Schematic illustrations of typical fire testing arrangements for mass timber enclosure assemblies: a) testing arrangement for fire resistance rating of a mass timber assembly, with flame typically applied to the interior face; b) exterior fire spread testing of a vertical enclosure assembly, with flame applied from the interior side through an opening and up the exterior face; c) firestopping testing for a floor-to-wall junction, with flame applied to the underside of the floor at the firestopping.*

The typical test standards used to determine the fire resistance ratings set out in codes are listed below. They vary depending on code/jurisdiction and generally are not interchangeable without approval.

- ASTM E119 Standard Test Methods for Fire Tests of Building Construction and Materials
- UL Standard 263: Fire Tests of Building Construction and Materials
- CAN/ULC-S101 Standard Methods of Fire Endurance Tests of Building Construction and Materials

## Exterior Fire Spread Performance

This code requirement addresses how a building's exterior façade that contains combustible components behaves under severe fire conditions. The requirement considers how the vertical structure and its enclosure materials (i.e., insulation, membranes, strapping), openings, and joints might contribute to fire spread and heat radiation on a building's exterior as well as the danger of falling materials due to fire. For this test, a large-scale vertical mock-up is tested with flame directed to the interior face of the system. Test conditions are intended to represent the fire exposure resulting from a fire in a compartment venting through a window opening in the wall (see Figure 18b). Many factors combine to determine pass or fail results, including heat flux sensor measurements and burning patterns. Note that this testing may focus on exterior combustible insulation or cladding, or on the mass timber elements.

The typical test standards used to determine the exterior fire spread performance for walls are:

- NFPA 285 Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Wall Assemblies Containing Combustible Components
- ULC CAN-S134 Standard Method of Fire Test of Exterior Wall Assemblies

Note that fire spread performance requirements often also apply to roof assemblies, but the testing and performance classification typically relates to exterior fire exposure of the roof covering material/membrane (i.e., Class A, Class B, or Class C), independent from the roof structure. Mass timber roof assemblies typically must have a Class A roof covering.



## Firestopping Performance

The penetrations and joints in mass timber enclosure systems must also meet firestopping performance criteria. This requirement is used to indicate that a firestopping system meets the appropriate fire resistance requirements for the assemblies they are contained within and/or adjoin. Note that while standard penetration and joint firestopping products like mineral wool and intumescent sealant may be used, these products may not be listed as approved for mass timber construction and may require specific testing or approval from a fire engineer. In particular, in façade systems that are hung from the building structure like a curtain wall, the floor-to-façade space is typically the basis for this testing to confirm the firestopping meets the code requirements (see Figure 18c).

The typical test standards used to determine the firestopping performance requirements for the interface between the exterior wall assembly and floor set out in codes are:

- ASTM E2307 Standard Test Method for Determining Fire Resistance of Perimeter Fire Barriers Using Intermediate-Scale, Multi-story Test Apparatus
- CAN/ULC-S115 Standard Method of Fire Tests of Firestop Systems

## Fire Protection During Construction

Building codes also typically restrict how much mass timber can be exposed during construction before it is fully encapsulated or other fire protection measures are put in place. For mass timber enclosures, this may mean that fire protection must be in place before the building is fully closed in and potentially while it is exposed to weather. See *Moisture Risk Management Strategies for Mass Timber Buildings*, also published by RDH, for more information on how to protect the mass timber structure from moisture exposure during the construction phase.

**This guide recommends that project-specific fire protection requirements are always confirmed with the local jurisdiction having authority, and that a dedicated fire protection consultant specializing in mass timber construction be retained for all mass timber projects.**

*Ronald McDonald House of British Columbia (Michael Green Architecture).*

# 3 – ENCLOSURE DESIGN APPLICATIONS

All building enclosures, including those constructed of mass timber, should be designed for the building's unique climate and indoor space use based on the building science and enclosure design fundamentals for managing water, air, thermal, and water vapor loads. Additionally, mass timber enclosures in service require dry and ideally near-room-temperature conditions to perform their best. In most cases, this means locating all or most of the required thermal insulation on the exterior of the mass timber element and providing space conditioning to regulate conditions when extreme indoor environments exist.

This chapter summarizes typical wall and roof assembly designs appropriate for mass timber enclosure elements located in either cold, heating-dominated climate zones in Canada and the Northern US (Climate Zones 4–8), or in hot-humid air-conditioning dominated climate zones in the Southern US (Climate Zones 1–3). See Figure 19 for climate zones in the US and Canada. Above-grade wall assemblies are summarized in Table 7 and consider exterior-insulated, split-insulated, and interior-insulated mass timber walls. The roof and floor assembly designs summarized in Table 8, Table 9, and Table 10 consider conventional and protected-membrane roof assembly designs and typical floor/soffit and and balcony assemblies.

In addition to following the recommendations provided with each of these assemblies, it is important to design and plan for moisture exposure during construction and occupancy of the mass timber structure and enclosure. Refer to RDH's *Moisture Risk Management Strategies for Mass Timber Buildings* publication for more guidance on best practice design approaches to minimize the risks associated with moisture exposure.

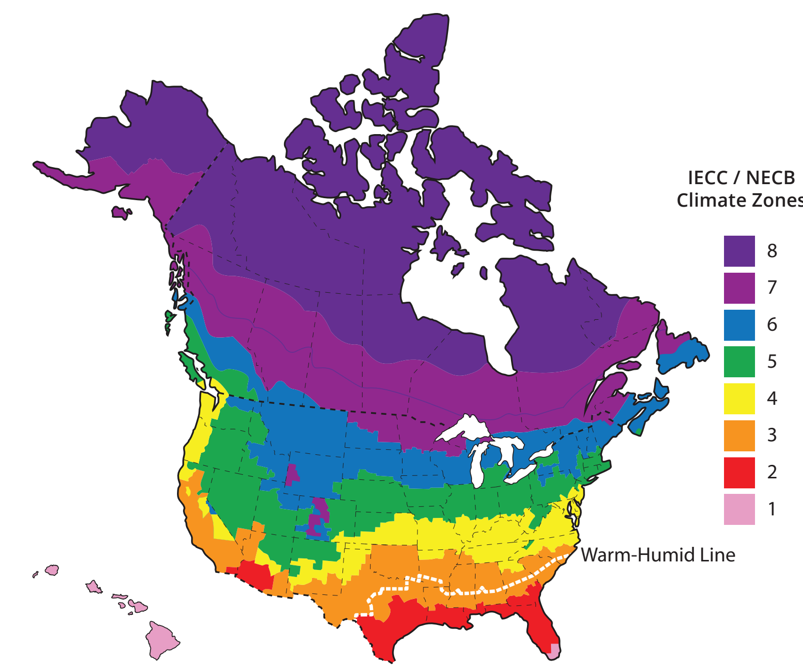
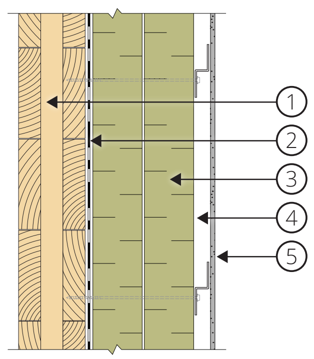
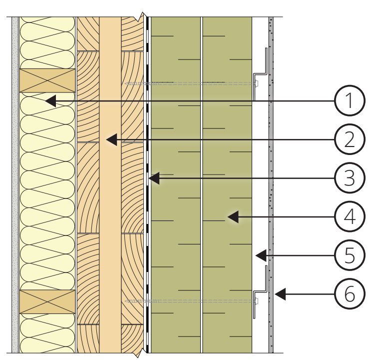
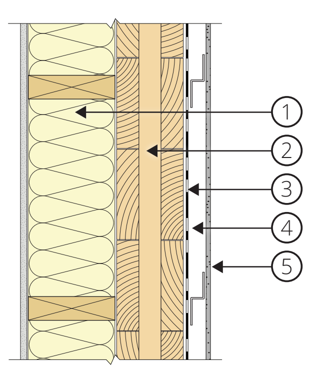



***Figure 19*** *US and Canada climate zone map [6], [23].*

*Table 7* *Wall Assembly Design Guidance for Climate Zones in the US and Canada**

| Wall Assembly<br>*(plan view)* | Assembly Layers<br>*(listed interior to exterior)* | Assembly Considerations |
|---|---|---|
| | **EXTERIOR-INSULATED WALL ASSEMBLY** | |
|  | **Legend**<br>**1.** Mass timber panel<br>**2.** Air barrier and water-resistive barrier<br>**3.** Exterior insulation<br>**4.** Ventilated and drained air cavity<br>**5.** Cladding | **General Discussion**<br>Exterior insulation is one approach for mass timber wall assemblies. It allows the mass timber to be left exposed to the interior where allowed by fire code. Exterior insulation keeps the mass timber warm and dry to a near-indoor condition. |
| | **SPLIT-INSULATED WALL ASSEMBLY** | |
|  | **Legend**<br>**1.** Interior insulation<br>**2.** Mass timber panel<br>**3.** Air barrier and water-resistive barrier<br>**4.** Exterior insulation<br>**5.** Ventilated and drained air cavity<br>**6.** Cladding | **General Discussion**<br>The use of both exterior and interior insulation may be desirable in some wall designs. This approach improves the overall effective R-value with less exterior insulation. It also benefits acoustics considerations by not leaving the mass timber exposed. This type of wall assembly should typically be assessed by a design professional. |
| | **INTERIOR-INSULATED WALL ASSEMBLY** | |
|  | **Legend**<br>**1.** Interior insulation<br>**2.** Mass timber panel<br>**3.** Air barrier and water-resistive barrier<br>**4.** Ventilated and drained air cavity<br>**5.** Cladding | **General Discussion**<br>The use of interior insulation improves the overall effective R-value of the assembly without the use of exterior insulation. This option still benefits acoustic considerations by not leaving the mass timber exposed. This type of wall assembly should typically be assessed by a design professional. |

* This guide recommends the use of a drained and ventilated rainscreen assembly and details for all mass timber walls in all climate zones. This rainscreen will also help to dissipate inward solar-driven moisture.



***Table 7 (continued)*** *Wall Assembly Design Guidance for Climate Zones in the US and Canada**

| Climate Zone Considerations | |
|---|---|
| **EXTERIOR-INSULATED WALL ASSEMBLY** | |
| **Climate Zones 1–3**<br>In a hot-humid climate, an exterior-insulated design approach could result in the condensation on the wood if it is not protected. In this environment, it is preferable to use either:<br>• A vapor-impermeable exterior insulation with a vapor-impermeable air barrier and WRB membrane, or<br>• A vapor-permeable exterior insulation if a vapor-impermeable exterior air barrier and WRB membrane is used.<br>Use caution when:<br>• Using a vapor-permeable exterior insulation and vapor-permeable air barrier and WRB membrane to avoid wetting the mass timber panel.<br>• Using impermeable materials on the exterior mass timber face, which can limit drying to only the interior. Use only with materials applied to very dry mass timber.<br>For this assembly design, use vapor-impermeable interior finishes if applied to or over the mass timber. This type of wall assembly should typically be assessed by a design professional. | **Climate Zones 4–8**<br>This is the preferred design approach for mass timber wall assemblies in this environment. The mass timber on the interior provides sufficient vapor resistance to outward vapor drive, eliminating the need for further vapor control. The use of vapor-permeable exterior insulation (>10 perms) and a self-adhered vapor-permeable air barrier and WRB membrane outboard of the mass timber is the most durable approach because it allows for outward drying of initially wetted mass timber or the drying of small leaks in service.<br>The use of either vapor-impermeable exterior insulation or a vapor-impermeable air barrier and WRB membrane can significantly limit outward drying and therefore should only be used with extreme caution with very dry mass timber.<br>Caution must be taken where the indoor relative humidity is expected to be elevated, such as in densely occupied housing, museums, and pools.<br>To achieve current building or energy code minimum prescriptive code R-values, 3 to 8 inches or more of exterior insulation will be required with a thermally efficient cladding attachment strategy. |
| **SPLIT-INSULATED WALL ASSEMBLY** | |
| **Climate Zones 1–3**<br>The guidance for exterior-insulated wall assemblies applies to this design approach as well. The interior insulation of this assembly must be vapor permeable (e.g., mineral fiber batts) to allow for inward drying and to not unintentionally trap moisture within the mass timber. Interior finishes are also vapor permeable. | **Climate Zones 4–8**<br>The guidance for exterior-insulated wall assemblies applies to this design approach; however, care must be taken to assess the ratio of exterior to interior insulation and material properties of the selected materials. The addition of interior insulation means that the mass timber panel will not be as warm as in the exterior-insulated case. Too much interior insulation could make the surface of the mass timber drop below the dewpoint of the indoor air and make the assembly at risk for condensation or moisture accumulation.<br>To reduce this risk, the insulation R-value of the exterior insulation should generally be 50% or more of the wall assembly total R-value for low-humidity spaces, and over 65% for moderate- and high-humidity spaces. This ratio can be conservatively determined by assessing the dewpoint temperature or more accurately using hygrothermal modeling.<br>The interior insulation is vapor permeable, and no supplemental vapor control layer is included on the interior. |
| **INTERIOR-INSULATED WALL ASSEMBLY** | |
| **Climate Zones 1–3**<br>Interior-insulated mass timber wall assemblies can perform acceptably in the far south where a high indoor vapor drive is expected. In these climate zones, the interior insulation and finishes are vapor permeable to prevent trapping moisture within the mass timber or interior cavity.<br>Care must be taken to limit the wetting or inward vapor drive from the outdoors by using a drained and ventilated rainscreen cladding. Non-absorptive claddings are preferable to absorptive claddings such as brick or stucco to reduce inward-driven moisture. The use of a semi-permeable air barrier and WRB membrane applied to the exterior of the mass timber panel may also be desirable to reduce the inward flow of vapor into the mass timber panel in some designs. Surface treatment of the mass timber panel may be necessary in very humid regions to limit the potential for microbial growth. | **Climate Zones 4–8**<br>Interior-insulated mass timber wall assemblies are not generally recommended in Climate Zones 4 through 8 except in unique indoor climatic situations and with special attention to the selection of materials and details. These exceptions may include cold-storage facilities and other unique indoor uses. In this assembly design, the interior insulation keeps the mass timber cold and damp (it will come into approximate equilibrium with the average outdoor relative humidity) and prone to air leakage and vapor diffusion condensation, further increasing moisture levels above ambient. Therefore, the interior insulation needs to be vapor impermeable to control wetting from the interior. This means that interior drying is not possible, and outward drying through the cold, damp mass timber is very slow. In all cases, a rainscreen cladding is highly recommended due to this highly sensitive design. |

*Table 8* *Conventional Roof Assembly Guidance for Climate Zones in the US and Canada*

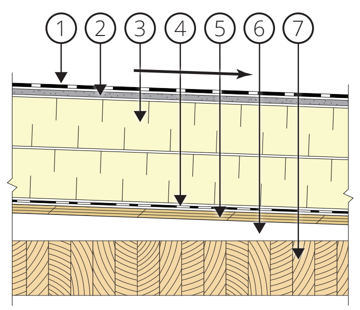
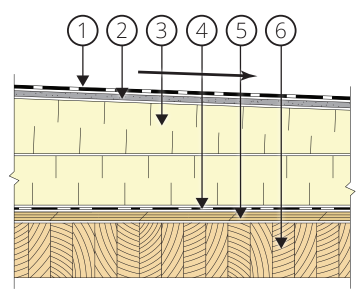
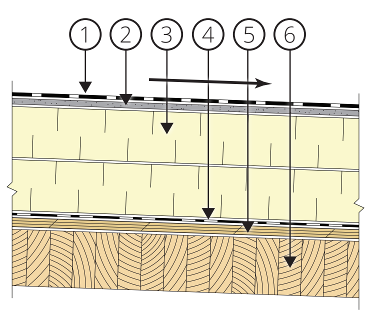
| Conventional Roof Assembly *(section view)* | Assembly Layers *(listed exterior to interior)* | Assembly and Climate Zone Considerations |
|---|---|---|
| SLOPED OVER-FRAMING ROOF ASSEMBLY | | **General Discussion**<br>The air and vapor barrier membrane in these assemblies when located over the top of the mass timber panel may also serve as protection to temporarily control moisture during the construction phase. When this membrane is flat (i.e., unsloped), plans are needed for draining water from this membrane during construction.<br>**Climate Zones 1–3**<br>A fully adhered roof membrane will typically serve as the air and vapor control layer. In this case, placing the air and vapor barrier membrane over the top of the mass timber panel (with sheathing where required) is often not necessary; however, a protective membrane may still be needed to temporarily manage construction phase moisture.<br>**Climate Zones 4–8**<br>Air control of these conventional roof assemblies is provided by the air barrier membrane. Primary vapor control of these conventional roof assemblies is typically provided by the mass timber panel.<br>The air barrier membrane may also be vapor impermeable to serve as a vapor barrier membrane where needed for temporary roof membrane purposes or to provide additional vapor control where an air cavity (vented to the interior) occurs above the mass timber panel.<br>The use of a vapor-permeable air barrier membrane may be suitable in some climates when there is a need to dry the roof assembly layers above the panel to the building interior; this approach requires analysis to ensure that outward vapor drive and inward drying are appropriately balanced. |
|  | **Legend**<br>1. Roof membrane<br>2. Coverboard<br>3. Rigid insulation<br>4. Air and vapor barrier membrane<br>5. Structural sheathing<br>6. Sloped over-framing, air cavity, vented to interior<br>7. Mass timber panel | |
| TAPERED INSULATION ROOF ASSEMBLY | | |
|  | **Legend**<br>1. Roof membrane<br>2. Coverboard<br>3. Rigid insulation<br>4. Air and vapor barrier membrane<br>5. Structural sheathing (where required)<br>6. Mass timber panel | |
| SLOPED STRUCTURE ROOF ASSEMBLY | | |
|  | **Legend**<br>1. Roof membrane<br>2. Coverboard<br>3. Rigid insulation<br>4. Air and vapor barrier membrane<br>5. Structural sheathing (where required)<br>6. Mass timber panel | |

*Table 9* *Protected-Membrane Roof Assembly Guidance for Climate Zones in the US and Canada*

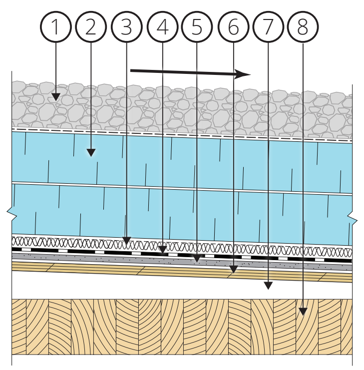
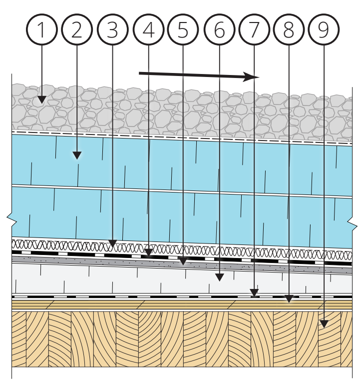
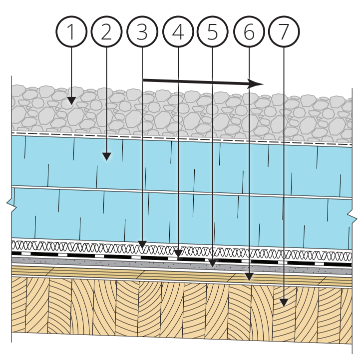
| Protected-Membrane Assembly *(section view)* | Assembly Layers *(listed exterior to interior)* | Assembly and Climate Zone Considerations |
|---|---|---|
| SLOPED OVER-FRAMING ROOF ASSEMBLY | | **General Discussion**<br>In a protected-membrane roof assembly, the roof membrane will provide air control for the assembly, unless a separate air barrier membrane is placed on the mass timber panel (such as in the tapered insulation roof assembly).<br>The roof membrane or air barrier membrane, whichever membrane is installed directly over the structural sheathing or mass timber panel, may serve to protect the mass timber during construction if the membrane is suitable for the anticipate level of moisture that the project may experience during this phase.<br>**Climate Zones 1–3**<br>A fully adhered roof membrane will typically serve as the air and vapor control layer and an additional membrane is not required.<br>**Climate Zones 4–8**<br>Primary vapor control of the protected-membrane roof assembly is typically provided by the mass timber panel. The air barrier membrane (such as in the tapered insulation roof assembly) may serve as a vapor barrier membrane where needed for temporary roof membrane purposes or to provide additional vapor control where an air cavity (vented to the interior) occurs above the mass timber panels. |
|  | **Legend**<br>1. Ballast<br>2. Extruded polystyrene insulation<br>3. Drainage composite<br>4. Roof membrane<br>5. Coverboard<br>6. Structural sheathing<br>7. Sloped over-framing, air cavity<br>8. Mass timber panel | |
| TAPERED INSULATION ROOF ASSEMBLY | | |
|  | **Legend**<br>1. Ballast<br>2. Extruded polystyrene insulation<br>3. Drainage composite<br>4. Roof membrane<br>5. Coverboard<br>6. Tapered rigid insulation<br>7. Air and vapor barrier membrane<br>8. Structural sheathing (where required)<br>9. Mass timber panel | |
| SLOPED STRUCTURE ROOF ASSEMBLY | | |
|  | **Legend**<br>1. Ballast<br>2. Extruded polystyrene insulation<br>3. Drainage composite<br>4. Roof membrane<br>5. Coverboard<br>6. Structural sheathing (where required)<br>7. Mass timber panel | |

*Table 10* *Floor and Soffit Assembly Guidance for Climate Zones in the US and Canada*

<table>
<tr><th>Floor and Soffit Assembly<br>*(section view)*</th><th>Assembly Layers<br>*(listed interior to exterior)*</th><th>Assembly and Climate Zone Considerations</th></tr>
<tr><td colspan="2">AIR-PERMEABLE INSULATION ASSEMBLY</td><td rowspan="4">

**General Discussion**

Air-impermeable flooring or sheathing placed over the top of mass timber panels (e.g., concrete topping or fully taped/sealed sheathing) may provide an alternative air barrier system if it is continuously detailed at all penetrations, assembly transitions, and interfacing details.

Acoustic components may be used to temporarily protect the mass timber from moisture exposure during construction or concrete topping placement depending on the material properties.

A waterproof floor coating should be considered where wet conditions or the risk of plumbing failures exists at the interior space.

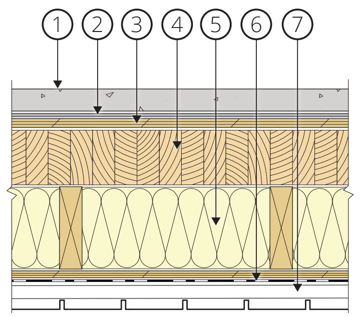
The vapor permeance of all assembly layers should be carefully considered relative to the mass timber panel and indoor and outdoor environmental conditions. It is undesirable to use vapor-impermeable exterior membranes or insulation in this application due to the potential for moisture to become trapped within the mass timber.

**Climate Zones 1–3**

Special consideration of the floor/soffit assembly is needed to avoid creating a double vapor barrier condition in this assembly. It is preferable to provide a vapor-permeable membrane and insulation on the underside of the mass timber to allow drying of the assembly; however, careful analysis is needed to balance the need for drying and potential for inward vapor drive.

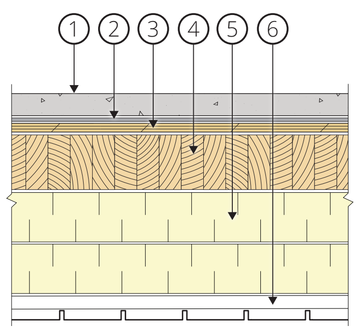
**Climate Zones 4–8**

The insulation and the air barrier membrane below the mass timber are vapor permeable to allow the assembly to dry to the exterior.

</td></tr>
<tr><td>
</td><td>

**Legend**

1. Interior finish
2. Acoustic components
3. Structural sheathing (where required)
4. Mass timber panel
5. Thermal insulation
6. Air barrier membrane
7. Soffit air space and panel

</td></tr>
<tr><td colspan="2">AIR-IMPERMEABLE INSULATION ASSEMBLY</td></tr>
<tr><td>
</td><td>

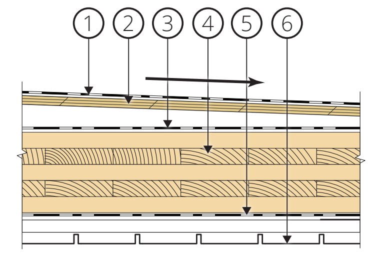
**Legend**

1. Interior finish
2. Acoustic components
3. Structural sheathing (where required)
4. Mass timber panel
5. Air- and vapor-impermeable insulation
6. Soffit air space and panel

</td></tr>
</table>



***Table 10 (continued)*** *Floor and Soffit Assembly Guidance for Climate Zones in the US and Canada*

<table>
<tr><th>Balcony Assembly<br>*(section view)*</th><th>Assembly Layers<br>*(listed interior to exterior)*</th></tr>
<tr><td colspan="2">SLOPED OVER-FRAMING</td></tr>
<tr><td>
</td><td>

**Legend**

1. Waterproofing membrane
2. Sheathing over sloped sub-framing
3. Air barrier membrane
4. Mass timber panel
5. Vapor-permeable air barrier membrane
6. Soffit air space and panel

</td></tr>
<tr><th colspan="2">Assembly and Climate Zone Considerations</th></tr>
<tr><td colspan="2">

**General Discussion**

The waterproofing membrane is intended to be a highly durable membrane that is trafficable, or concealed with a trafficable finish material, to protect the moisture-sensitive mass timber assembly from water exposure.

The waterproofing membrane is sloped to encourage water to shed away from the structure. Sheathing over sloped over-framing or blocking creates the slope in this assembly. Consider reducing the mass timber panel thickness at balcony locations to avoid slope rise and accessibility conflicts.

The air barrier membrane is shown placed around the mass timber structure to minimize air movement into the assembly through mass timber joints and gaps; however, the necessity for the air barrier membrane to extend around the panel will depend on the mass timber panel type and the project-specific wall-to-balcony connection.

This assembly is high risk for moisture intrusion at peripheral slab edges, especially those with railing connections. Care must be taken to design appropriate water control and railing attachment methods to reduce the risk for water to reach the mass timber panel.

**Climate Zone Considerations**

Condensation risk for this assembly, especially in cold climates, requires careful consideration. Condensation risk of this uninsulated assembly can be reduced by limiting the movement of interior air into the panel to the greatest extent possible and by using vapor-permeable materials beneath the soffit to allow for bottom-side drying.

</td></tr>
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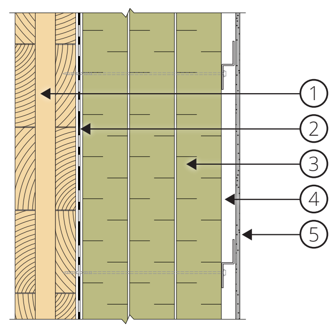



**Legend**

*(listed interior to exterior)*

1. CLT wall panel
2. Air barrier and WRB membrane
3. Exterior insulation
4. Ventilated and drained air cavity
5. Cladding

***Figure 20*** *Super-insulated mass timber enclosure wall assembly (plan view).*

# HIGHER-PERFORMING ENCLOSURES

Building codes across the US and Canada continue to increase their energy performance requirements, leading to a need for higher-performing, more thermally efficient building enclosure systems. The trends signify that the future of building enclosures lies with designs that support passive house, net-zero energy, and net-zero carbon concepts. These frameworks are growing in popularity throughout the US and Canada and alongside alternative materials such as mass timber wall and roof panel products.

Higher-performing enclosures are used on buildings that are required to achieve specific performance values for conditioning energy use intensity, total energy use intensity, spatial temperature variation, heat recovery ventilation performance, and air leakage. These performance benchmarks are reaching mainstream construction and proving to be possible with mass timber enclosure assemblies. Mass timber assemblies support durable, low-conductivity enclosure designs and increased airtightness performance while also offering a low-carbon, penalization option. A glimpse at the marriage of these concepts using an exterior-insulated wall assembly approach is shown in Figure 20 and Figure 21 and discussed throughout this section.

The design concepts for a typical exterior-insulated mass timber wall assembly still apply to these higher-performing enclosures but are often prefabricated and their low-conductivity thermal performance and airtightness expectations are heightened.

a)

b)

***Figure 21*** *A full-scale mock-up of a super-insulated mass timber enclosure wall assembly showing a) the mock-up visible from the exterior, and b) the depth of insulation and transition at a floor line.*



Heightened thermal performance requirements of the wall assembly require continuous and relatively deep application of exterior insulation (i.e., super-insulated) compared to more conventional assemblies. To preserve the continuity of the improved thermal separation, thermal bridging is kept to a minimum for cladding attachments and flashing elements. The cladding is attached using engineered systems comprised of long, stainless steel screws with furring strips. This approach results in only intermittent, point-based thermal bridging from the cladding to the exterior condition to the face of the mass timber panel behind the thermal enclosure. Additionally, conventional cross-cavity sheet metal flashing elements, which typically disadvantage an assembly's thermal conductivity, are replaced with two-part silicone rubber/membrane flashing products partially supported by the exterior insulation; these flashing products are extended onto the sheet metal trim and flashing installed outboard of the insulation layer. As a result, thermal bridging from the cross-cavity sheet metal elements is significantly minimized from the design.

Given the increased complexity of the cladding attachment system and an aggressive project schedule, higher-performing mass timber enclosure systems often rely on varying levels of prefabrication prior to delivery to the project site. In some instances, the entirety of the panel system—including the mass timber, enclosure membranes, high-performance glazing systems, exterior insulation, cladding attachment system, and cladding—is provided from a single prefabrication facility which, due to accessibility for installation and climate-controlled conditions, often increases quality installation and quality control. This prefabrication process increases the pace of construction, reduces variability in the field installation conditions, and largely avoids the installation of elements contributing to thermal bridging. However, the panelized prefabrication method creates joints within the enclosure that require a novel approach to airtightness.

To maintain airtightness between prefabricated enclosure panels, high-performance panelized systems rely on the existing technologies of gaskets and aluminum tracks typical of curtain wall construction. During prefabrication, the head, sill, and jamb conditions are fitted with track receivers or starter tracks that permit the installation of gaskets between the panels. These gaskets are installed in such a way that air-tightness is maintained from panel to panel without forming a rigid connection, as shown in Figure 22. As a result, panel movement, which is expected during and after construction from building movement, structural live loads, or seismic events, is accommodated without degrading airtightness performance. In this arrangement, the panels function in much the same way that other unitized systems maintain airtightness. As the demand for higher-performing enclosure assemblies continues to gain traction, the continued adaptation of more common building enclosure materials, assemblies, and systems to meet this demand is expected.

One example of meeting this demand is the exploration of lower-conductivity attachment methods and detailing, such as the balcony mock-up design shown in Figure 23 and Figure 24. In this example, custom steel connections allow for flexibility in attachment to accommodate construction tolerances and minimize thermal bridging across the enclosure plane.

***Figure 22*** *A horizontal stack joint concept at a panel-to-panel connection shown on a super-insulated wall assembly mock-up.*

***Figure 23*** *A custom steel connection provides intermittent attachment of the balcony element to the wall, reducing thermal bridging across the exterior wall insulation (not shown) at the interface.*

***Figure 24*** *A two-story balcony mock-up. Visible space between the balcony elements and CLT wall panel will be filled with insulation, flashing, and cladding elements.*

*Mass timber building under construction.*

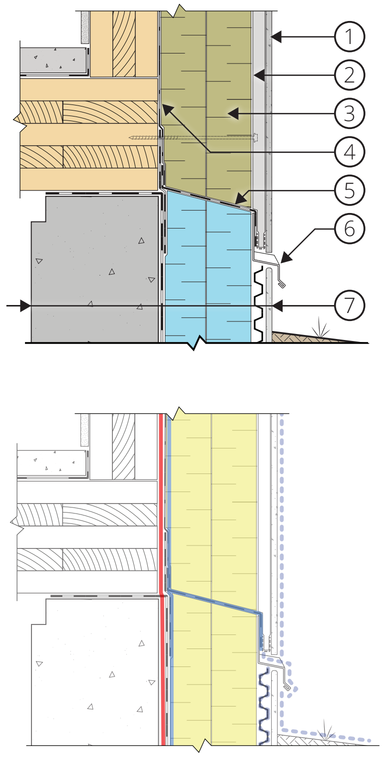
# 4 – MASS TIMBER ENCLOSURE DETAILING

As discussed in Chapter 2, using the control layer concept when evaluating assemblies and details is an industry best practice and can lead to a better understanding of how an assembly and associated details function. When evaluating mass timber enclosure assemblies, it's important to confirm that each detail includes the following layers:

- **Water control layer:** Provides continuous control of water through continuous water-shedding surfaces such as cladding, flashings, trims, and roof membranes, and through the use of continuous water control membranes, such as the roof/waterproofing membrane and WRB membrane. This includes up and over parapets, into rough openings, and out onto penetrations or projections through the enclosure.
- **Air control layer:** Provides continuous control of air exchange between the interior and exterior by providing a system of continuously sealed products that can resist air flow. To be most effective, the air barrier system should wrap around all mass timber elements because it is difficult to restrict air flow through panels and at panel connections.
- **Thermal control layer:** Provides continuous thermal control by locating the insulation in a similar plane throughout the enclosure. This includes thermal insulation up and over parapets, below soffits, and up to window systems.
- **Vapor control layer:** Provides vapor control but it does not need to be continuous to be effective. As previously discussed, mass timber panels provide vapor control; however, the interfaces, connections, and thermal bridges through the enclosure need to be carefully evaluated for condensation risk potential.

Several common mass timber enclosure details and their corresponding control layers are shown in Figure 25 through Figure 30.

# AT-GRADE DETAIL

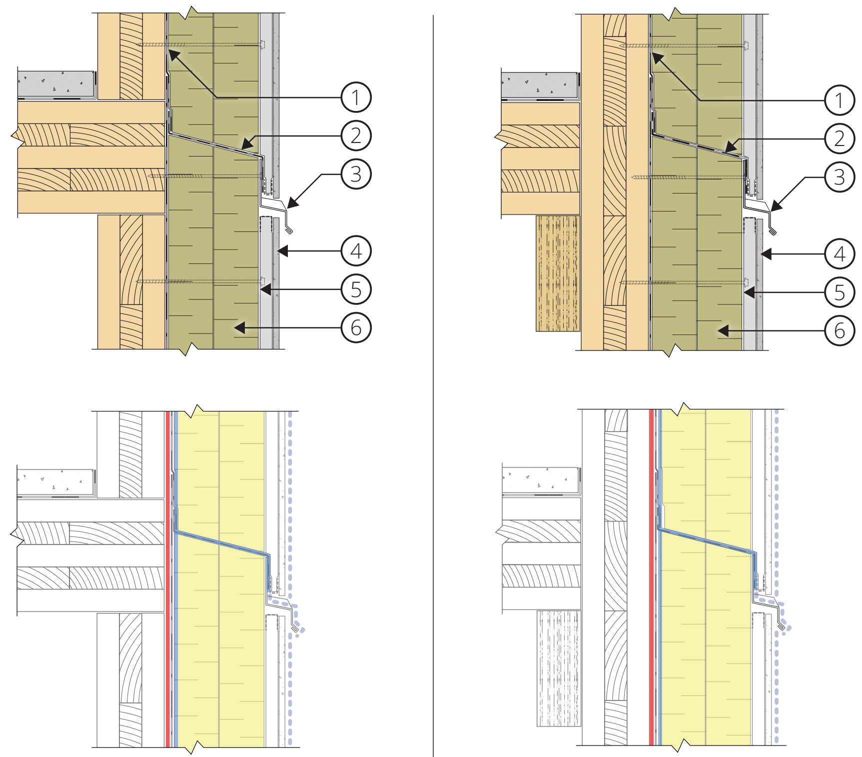



### Legend

1. Cladding
2. Ventilated and drained air cavity
3. Exterior insulation
4. Air barrier and WRB field membrane
5. Cross-cavity flexible flashing membrane
6. Sheet metal flashing
7. Below-grade wall assembly

***Figure 25*** *Typical mass timber at-grade detail.**

# FLOOR LINE DETAILS




a) Platform-framed floor line

b) Balloon-framed floor line

### Legend

1. Air barrier and WRB field membrane
2. Cross-cavity flexible flashing membrane
3. Sheet metal flashing
4. Cladding
5. Ventilated and drained air cavity
6. Exterior insulation

### Legend

1. Air barrier and WRB field membrane
2. Cross-cavity flexible flashing membrane
3. Sheet metal flashing
4. Cladding
5. Ventilated and drained air cavity
6. Exterior insulation

***Figure 26*** *Typical mass timber floor line details at a) a platform-framed floor line condition, and b) a balloon-framed floor line condition.**

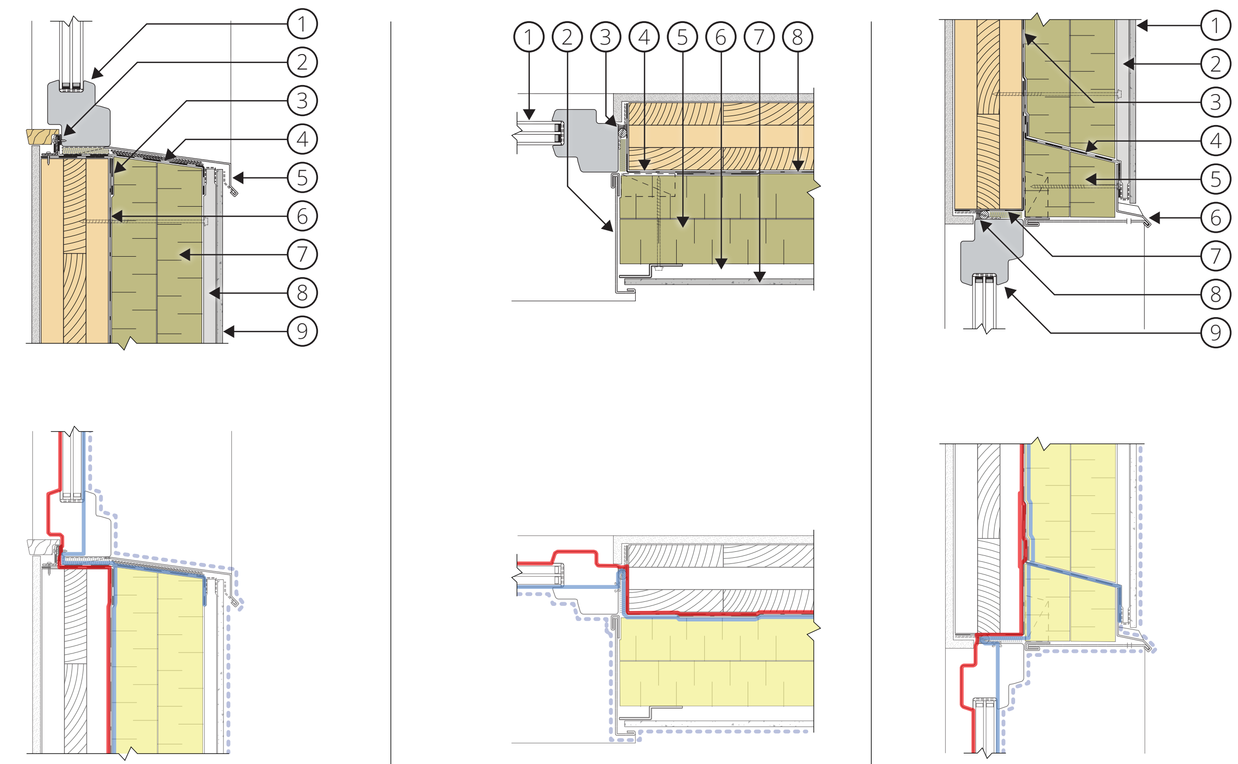
### Control Layers Legend

- Water-Shedding Surface
- Water Control
- Air Control
- Thermal Control

**Vapor control is provided by the mass timber panel in heating-dominated climates and is not shown on this figure for clarity. Refer to the assembly tables in Chapter 3 of this guide for more discussion on assembly-specific vapor control.*



# WINDOW PENETRATION DETAILS




a) Sill condition

b) Jamb condition

c) Head condition

### Legend

1. Window system
2. Air barrier and WRB sealant between window and metal back dam angle
3. Air barrier and WRB membrane (rough opening prestrip)
4. Secondary sill drainage membrane
5. Window sill flashing
6. Air barrier and WRB field membrane
7. Exterior insulation
8. Ventilated and drained air cavity
9. Cladding

### Legend

1. Window system
2. Jamb closure
3. Air barrier and WRB sealant over backer rod
4. Air barrier and WRB membrane (rough opening prestrip)
5. Exterior insulation
6. Ventilated and drained air cavity
7. Cladding
8. Air barrier and WRB field membrane

### Legend

1. Cladding
2. Ventilated and drained air cavity
3. Air barrier and WRB field membrane
4. Window head flexible flashing membrane
5. Exterior insulation
6. Window head flashing and closure
7. Air barrier and WRB membrane (rough opening prestrip)
8. Air barrier and WRB sealant over backer rod
9. Window system

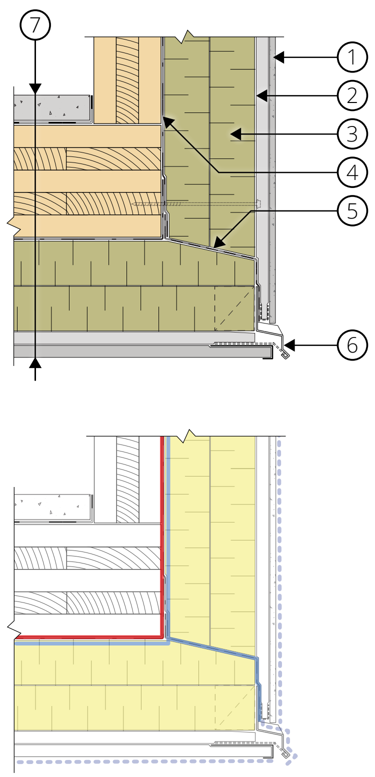
***Figure 27*** *A typical window penetration detail series including a) sill condition, b) jamb condition, and c) head condition. Vapor control is provided by the mass timber panel (in heating-dominated climates) and the window system.**

### Control Layers Legend

- Water-Shedding Surface
- Water Control
- Air Control
- Thermal Control

**Vapor control is provided by the mass timber panel in heating-dominated climates and is not shown on this figure for clarity. Refer to the assembly tables in Chapter 3 of this guide for more discussion on assembly-specific vapor control.*

## SOFFIT-TO-WALL DETAIL

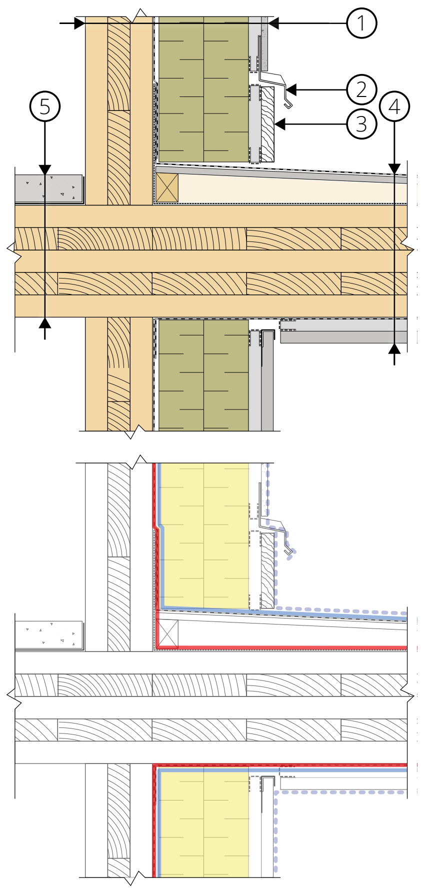



### Legend

1. Cladding
2. Ventilated and drained air cavity
3. Exterior insulation
4. Air barrier and WRB field membrane
5. Cross-cavity flexible flashing membrane
6. Sheet metal flashing
7. Soffit assembly

***Figure 28*** *Soffit-to-wall detail.**

## BALCONY-TO-WALL DETAILS




### Legend

1. Wall assembly
2. Sheet metal flashing
3. Base trim
4. Balcony assembly
5. Interior floor assembly

***Figure 29*** *Typical mass timber balcony-to-wall detail.**

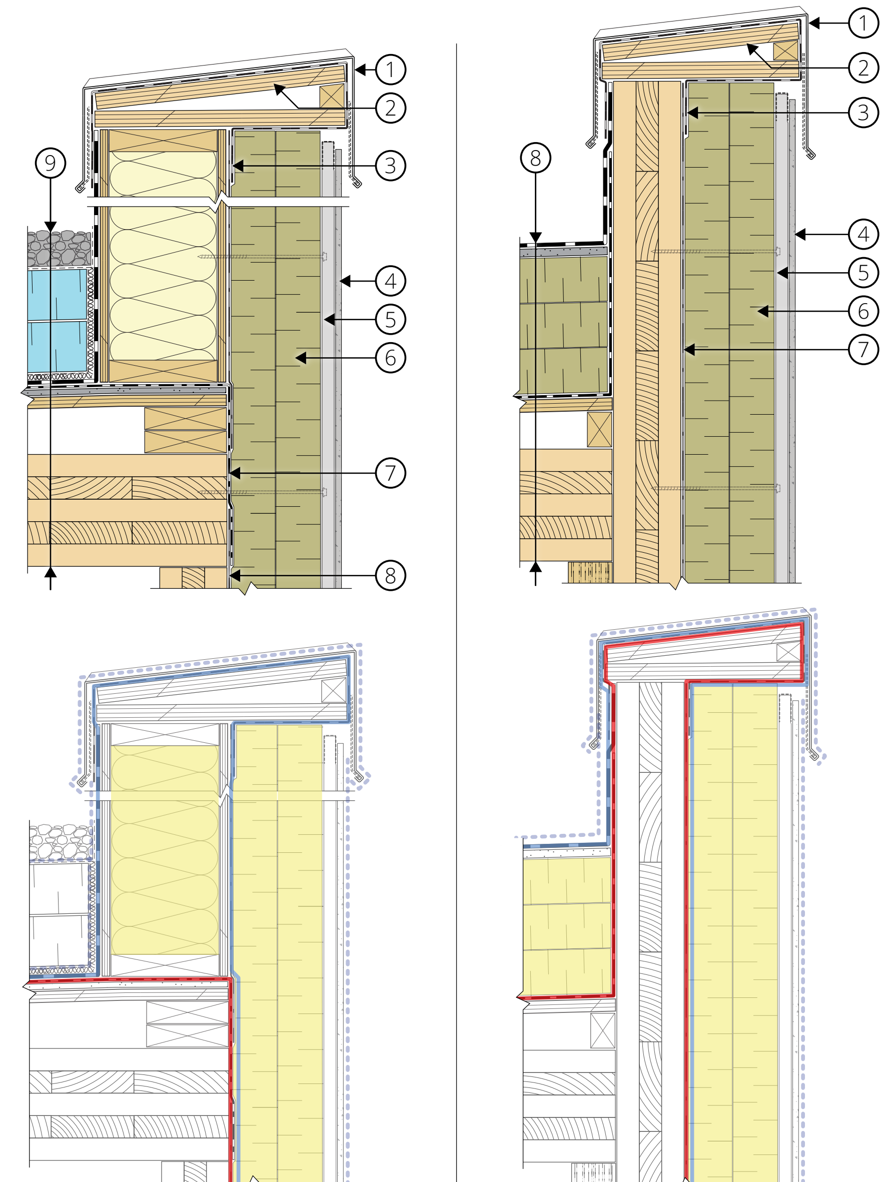
### Control Layers Legend

Water-Shedding Surface
Water Control
Air Control
Thermal Control

**Vapor control is provided by the mass timber panel in heating-dominated climates and is not shown on this figure for clarity. Refer to the assembly tables in Chapter 3 of this guide for more discussion on assembly-specific vapor control.*



## ROOF PARAPET DETAILS




**a) Platform-framed parapet**

**b) Balloon-framed parapet**

### Legend

1. Sheet metal coping
2. Sloped parapet blocking
3. Parapet flashing membrane
4. Cladding
5. Ventilated and drained cavity
6. Exterior insulation
7. Air barrier parapet prestrip membrane
8. Air barrier and WRB field membrane
9. Protected-membrane roof assembly

### Legend

1. Sheet metal coping
2. Sloped parapet blocking
3. Parapet flashing membrane
4. Cladding
5. Ventilated and drained cavity
6. Exterior insulation
7. Air barrier and WRB field membrane
8. Conventional roof assembly

### Control Layers Legend

Water-Shedding Surface
Water Control
Air Control
Thermal Control

***Figure 30*** *Typical mass timber details at a) platform-framed parapet condition, and b) balloon-framed parapet condition. The location of vapor control will vary by climate and is not shown for clarity; refer to the assembly tables in Chapter 3 of this guide for more discussion on assembly-specific vapor control.*

*Ronald McDonald House of British Columbia (Michael Green Architecture).*

# 5 – CONCLUSION

Mass timber is an attractive option for building enclosures that offers heightened construction speed and compatibility with today's energy performance standards. Mass timber's unique physical properties—a relatively high capacity to store moisture and a relatively slow potential for drying—require design and construction teams to pay special attention to certain aspects of the enclosure to ensure the long-term durability of the building.

Thoughtful design of the building enclosure requires consideration of all loads imposed on the enclosure over its expected service life. The designer must consider climate, microclimate, site conditions, and building use and operation when evaluating the loads acting on the enclosure. Designers who work on mass timber enclosure designs can apply the industry best practice of identifying and evaluating the enclosure's control layers to ensure that each project will meet performance expectations.

The best practices outlined in this guide consider how mass timber's unique properties are impacted by the water, air, thermal, and water vapor loads that act on a mass timber enclosure. These best practices offer guidance on thoughtfully designing a mass timber enclosure to control these loads and are summarized in this chapter.

For additional design guidance and recommendations on minimizing moisture-related risks in mass timber roof and floor systems during construction and occupancy, please consult the companion guide titled *Moisture Risk Management Strategies for Mass Timber Buildings*, also published by RDH Building Science.

*Designers who work on mass timber enclosure designs can apply the industry best practice of identifying and evaluating the enclosure's control layers to ensure that each project will meet performance expectations.*

# WATER CONTROL BEST PRACTICES

For a mass timber enclosure, the most critical load is often liquid water. The dimensional changes that occur when wood absorbs water can create gaps or collisions and checking, and moisture exposure can increase the risk for microbial growth, decay, and corrosion of metal fasteners or connectors. Mass timber panels can retain large amounts of water for extended periods of time if drying conditions are insufficient, further increasing the risk of damage and/or degrading the structural integrity of the mass timber component.

Best practices for water control in mass timber assemblies are summarized below:

- ☑ Consider that taller mass timber buildings are likely to see greater water loads due to the impact of wind-driven rain than shorter wood-framed structures.
- ☑ Avoid vapor-impermeable materials exterior of mass timber because they have the potential to trap moisture within the mass timber panel and limit drying through vapor diffusion.
- ☑ Use a drained and ventilated rainscreen cladding with rainscreen details for water control in mass timber walls like the example shown in Figure 31.
- ☑ Install a durable, fully adhered (e.g., multi-ply) roof membrane on the roof to promote long-term performance of the roof assembly, especially where temporary roof membranes over the mass timber structure are not used.
- ☑ Follow best practice guidance for general roof design and installation of materials in roofing manuals developed by the National Roofing Contractors Association.
- ☑ Treat areas such as bathrooms, showers, laundry rooms, and food-preparation areas with a waterproofing system and drainage for incidental water to reduce the moisture exposure of the mass timber floor panel.

***Figure 31*** *Vertical strapping installed over exterior insulation to create a drainage cavity in the rainscreen wall assembly.*



# AIR CONTROL BEST PRACTICES

Managing airflow across the building enclosure, which is a requirement of US and Canadian building codes, reduces energy consumption, increases thermal comfort, minimizes water vapor movement, and minimizes the transfer of sound, smoke, fire, and airborne contaminants between environments. Airflow management is accomplished with an air barrier system. In mass timber panels, the interfaces between the panels and the small spaces between each lamination of the panel allow air to pass through when the panels are structurally connected, so mass timber panels are not part of the air barrier system. Therefore, best practices for air control in mass timber assemblies focus on the selection, design, and installation of the air barrier system.

Best practices for air control in mass timber assemblies are summarized below:

- ☑ Ensure the air barrier system is durable enough to withstand the temperature fluctuations, building and wood substrate movement, air pressure differentials, and environmental exposures (e.g., UV and contaminants) that may occur during the building's life cycle.
- ☑ Ensure the air barrier system materials have the durability and strength during the construction phase to withstand UV exposure, moisture exposure, wind pressures/gusts, and trade activities.
- ☑ Extend the air barrier system continuously around all mass timber components, including around soffits, up and over parapets, and across floor lines to ensure the air barrier system is continuous at all joints, penetrations, and interfaces with other assemblies, like the example shown in Figure 32.
- ☑ Apply a fully adhered air barrier membrane directly on the wood panels so the membrane's adhesion to the stiff wood substrate will resist both positive and negative airflow pressures.


***Figure 32*** *In-progress installation of a self-adhered vapor-permeable air and WRB wall membrane. The wall membrane is continuous with the air barrier membrane at the roof.*

# THERMAL CONTROL BEST PRACTICES

The thermal load on building enclosures tends to be more influential in colder climates, but insulation is an essential component for energy-efficient buildings in most, if not all, climate zones in the US and Canada. Most building codes across the US and Canada require minimum levels of insulation. Insulation improves the thermal comfort for the occupants, provides a buffer from outdoor noise, and helps manage condensation risk within the enclosure.

Although insulation is the primary means of thermal control, mass timber panels can contribute to the assembly's thermal performance because wood has a relatively low thermal conductivity compared to other common structural materials. The mass of the timber panel can also impact the thermal performance of the assembly by moderating heat flow through thermal storage. However, the thermal resistance of the wood panel alone is usually not great enough to meet the required thermal performance of the assembly, so additional insulation is needed.

Best practices for thermal control in mass timber assemblies are summarized below:

- ☑ Locate the insulation outboard of the wood panel, as shown in Figure 33, to keep the wood panel closer to the indoor temperature. This practice will minimize the condensation risk and limit temperature and relative humidity fluctuations.
- ☑ Consult applicable building codes and the local authority having jurisdiction to determine prescriptive insulation requirements for mass wall and floor assemblies.

***Figure 33*** *Rigid insulation located exterior of the mass timber walls.*



# WATER VAPOR CONTROL BEST PRACTICES

Like liquid water, water vapor is an important factor in the design and performance of a mass timber assembly. The wood panels exchange moisture with the surrounding air, and the wood swells when it gains moisture and shrinks when it loses moisture. The amount of moisture gain or loss largely depends on the relative humidity but also on temperature and other factors. When the wood no longer gains or loses moisture, it has reached equilibrium with the environment.

Dimensional changes are the greatest in the direction of the annual growth rings—about half as much across the growth rings and usually very small along the grain.

Best practices for water vapor control in mass timber assemblies are summarized below:

- ☑ Consider both the interior and exterior project-specific climates when locating insulation and vapor control layers. Ensure that a potential for assembly drying is maintained and that risk for condensation to form within the assembly is limited.
- ☑ Avoid adding a vapor barrier or other low-permeability material, which reduces the drying potential of the mass timber panel. Instead, rely on the mass timber's ability to function as a vapor retarder and install vapor-permeable membranes in assemblies with exterior air barriers like those shown in Figure 34.
- ☑ Avoid assemblies where mass timber is encapsulated by impermeable materials, such as in a floor with a cementitious topping and membrane on top and an impermeable membrane or finish below.

***Figure 34*** *Vapor-permeable self-adhered air barrier and WRB membrane installed on a mass timber prefabricated panel while at the factory.*

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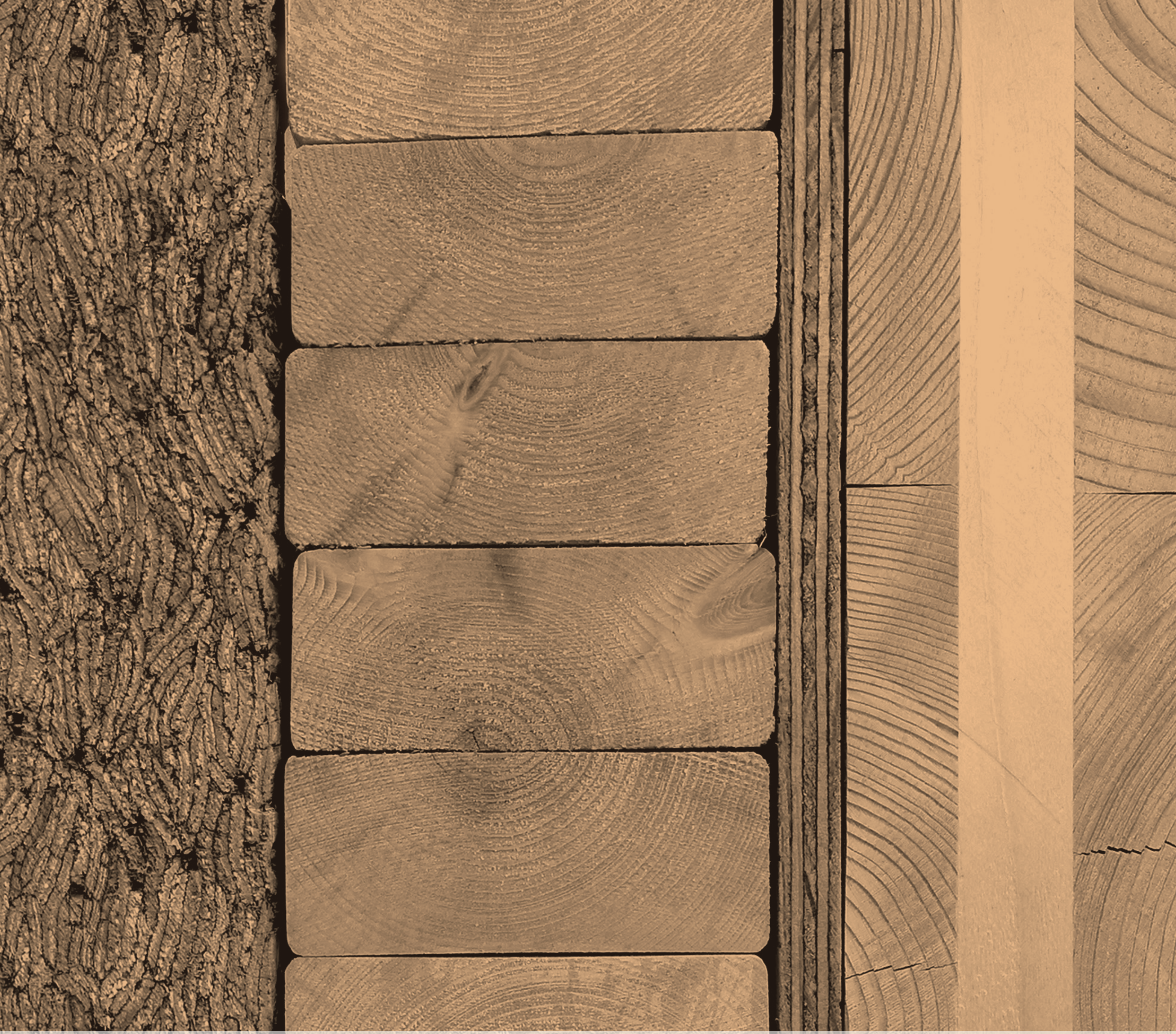
# ADDITIONAL RESOURCES

Additional resources for guidance on best practice enclosure design principles for mass timber enclosures include the following:

- *Cross-Laminated Timber (CLT) Handbook*, FPInnovations and RDH Building Science
- *Nail-Laminated Timber: U.S. Design and Construction Guide*, RDH Building Science
- *Nail-Laminated Timber: Canadian Design and Construction Guide*, RDH Building Science
- *Technical Guide for the Design and Construction of Tall Wood Buildings in Canada*, RDH Building Science
- *ANSI/APA PRG 320: Standard for Performance-Rated Cross-Laminated Timber*, American National Standards Institute and APA–The Engineered Wood Association
- *Moisture Risk Management Strategies for Mass Timber Buildings*, RDH Building Science
- *Encapsulated Mass Timber Construction Up to 12 Storeys*, Architectural Institute of British Columbia and Engineers & Geoscientists British Columbia
- *Mass Timber Building Science Primer*, Mass Timber Institute

Many of the above resources can be accessed through RDH's online technical library at https://www.rdh.com/technical-library/.



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